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August 1990 **U.S. $2.50**
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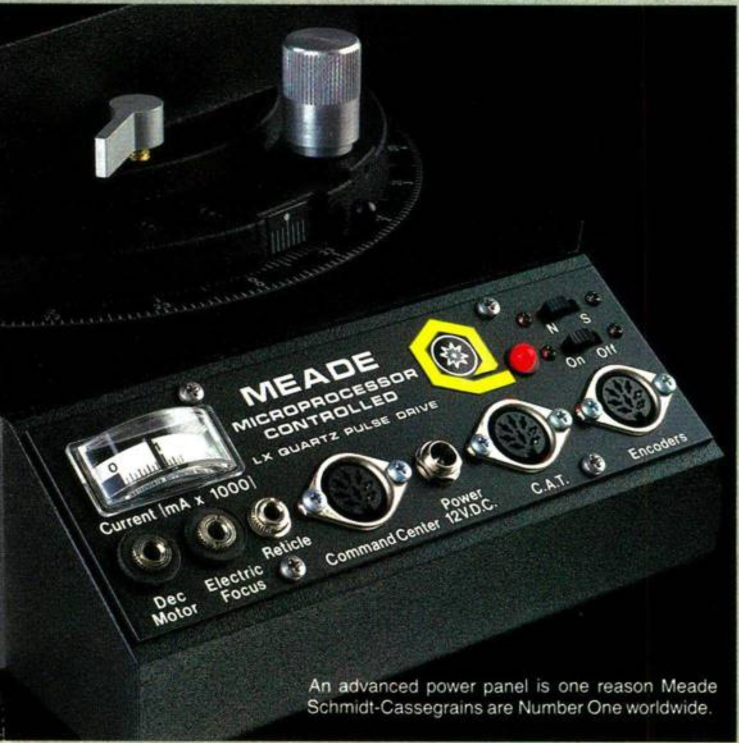


An advanced power panel is one reason Meade Schmidt-Cassegrains are Number One worldwide.

Using technology developed for the Meade 16″ Schmidt-Cassegrain, the Smart Drive yields observatory drive accuracy on all Meade Premier Series 8″ and 10″ SCT's:

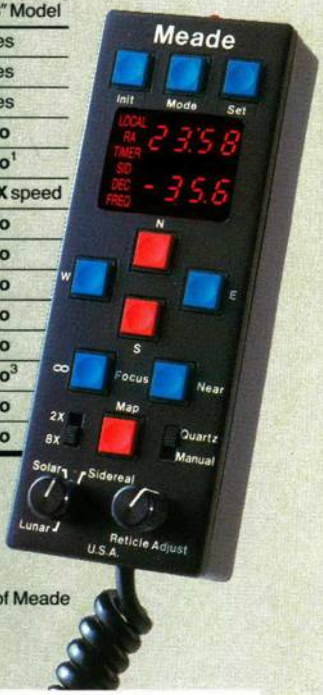
- **Automatically effects microcorrections** in the telescope's drive rate, to compensate for recurring worm gear errors.
- **Once programmed into its microprocessor memory,** required periodic error corrections are **permanently** retained by the Smart Drive—even when the telescope is turned OFF.
- **Competing "un-smart" periodic error correction devices** require that you re-train the periodic memory algorithm **each time you use the telescope**—a chore at best.
- **Meade Smart Drive technology reduces worm gear periodic error by up to 90%,** enabling vastly easier long-exposure astrophotography, with far fewer required corrections and fewer chances for guiding errors.
- **The Smart Drive is now available on all Meade 8″ and 10″ Premier Series Schmidt-Cassegrains**—from the budget-priced 8″ 30-Series to the advanced 10″ 70-Series, and on every model in between.
- **Using optional CCD's currently available,** the Smart Drive can be programmed to yield periodic errors as low as 1 arc sec.!
- **Previous Meade 8″ and 10″ Schmidt-Cassegrain models** may be upgraded to the Smart Drive—see your Meade dealer for details.
- **For complete information on the Meade Smart Drive**—and a point-by-point comparison with competing models—send $3.00 for your copy of the Meade 1990 Catalog #90C.

More Reasons Why Serious Amateurs Worldwide Buy Meade Schmidt-Cassegrains:

Month after month, year after year, in Japan, in Europe, and in the U.S.A., Meade Schmidt-Cassegrains outsell the competition. Why? Among other reasons, compare the hand control/power panel standard-equipment listings of the Meade 8″ 2080/Model 50 (our mid-price-range 8″ SC) with the competition's top-of-the-line 8″ model that sells for hundreds of dollars more! You get more for your money with a Meade.

	Meade 8″ 2080/Model 50	Competing 8″ Model
North-South Operation	Yes	Yes
Map Light	Yes	Yes
2X Corrections East-West	Yes	Yes
2X Corrections North-South	Yes	**No**
Declination Motor	Yes	**No**[1]
RA Slewing	8X speed	**4X** speed
Declination Slewing	8X speed	**No**
Continuously Variable Freq. Control	Yes	**No**
Illuminated Reticle Control	Yes	**No**
Optional Digital Readouts	Yes[2]	**No**
Optional CCD Connectors	Yes	**No**
AC and DC Adapters	Yes	**No**[3]
Ammeter	Yes	**No**
CAT™ Computer Outlet	Yes	**No**

[1] Optional Dec. motor priced at $170 additional. [2] Includes digital coordinate readouts; digital timer; RA freq. display with King rate; local time; sidereal time. [3] Optional adapters priced at $58 additional.



The full-featured hand controller of Meade 8″ and 10″ Premier Series SCT's.

Meade Optical Systems—The Best Gets Better: Long recognized as the finest commercially-produced Schmidt-Cassegrains available, Meade SC optics have now been refined still further by the addition of new state-of-the-art laser collimators. *Meade optical technicians now orient, collimate, and test Meade SC optics to tolerances that competing SC's simply can not reach on any consistent basis.* Meade 8″ and 10″ SC optics are warranted, without qualification, to be the smoothest, most precisely corrected SC systems ever manufactured.

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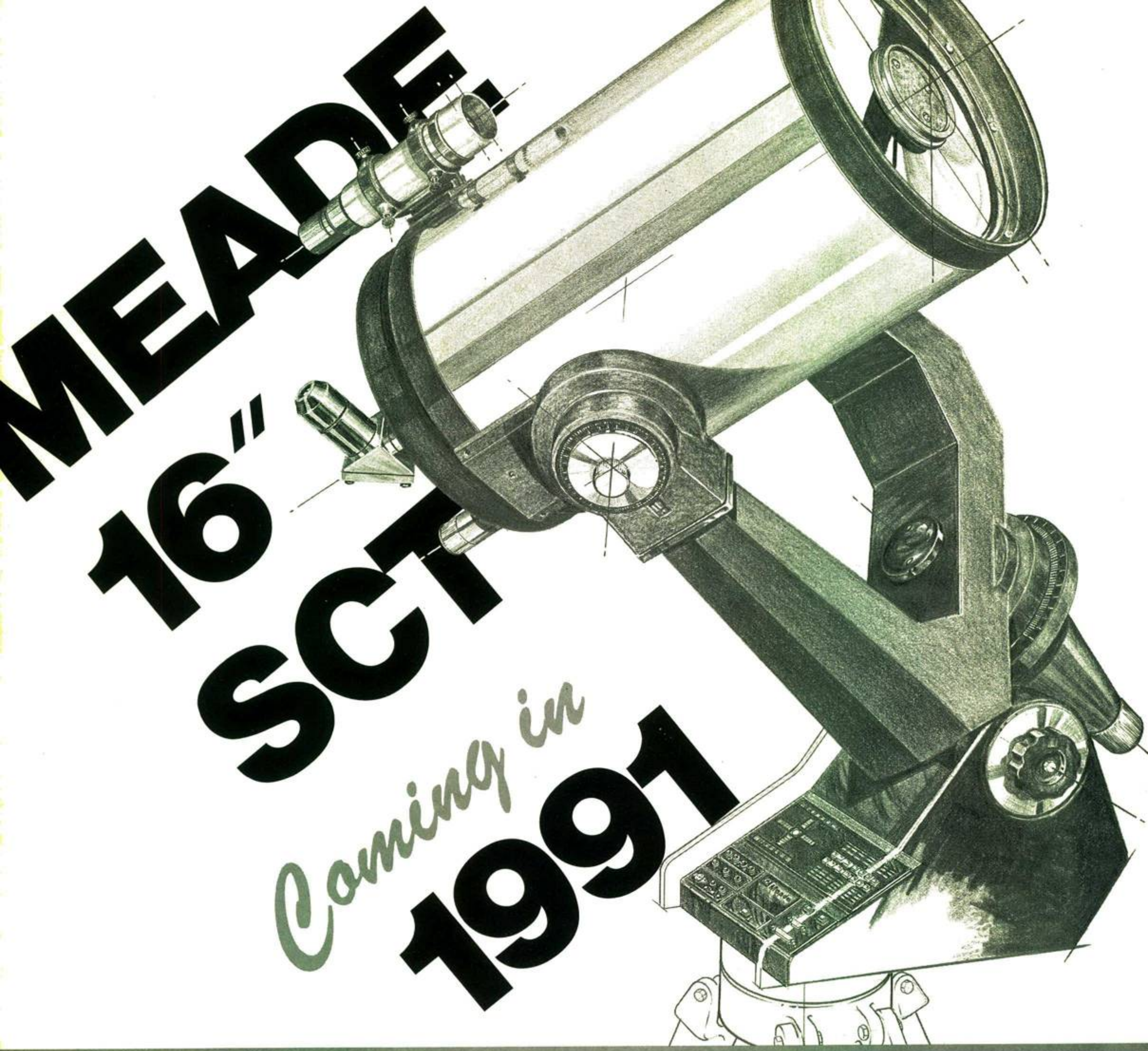


Eagerly anticipated throughout its 3-year development, this greatest of all Meade Schmidt-Cassegrains, the 16″ Model 2600, will be available for delivery in early-1991.

Designed for the school or college observatory, or for the advanced amateur, the Model 2600 offers optional state-of-the-art technology unavailable on any other telescope priced under $30,000:

■ **PC interface and access** to the telescope's microprocessor I/O ports offer almost limitless control options. Imagine opening the observatory dome, powering up the telescope, rapidly slewing to a designated object, taking a timed exposure, parking the telescope, powering down the telescope, and closing the dome—all from a remote location.

■ **Integrated high-resolution optical encoders** transmit R.A. and Declination data to an advanced version of the CAT™ Computer Aided Telescope and to digital readouts in the hand controller.

■ **Automatic-slew in R.A. and Dec. at 6° per second** to arbitrary coordinates input at the hand controller.

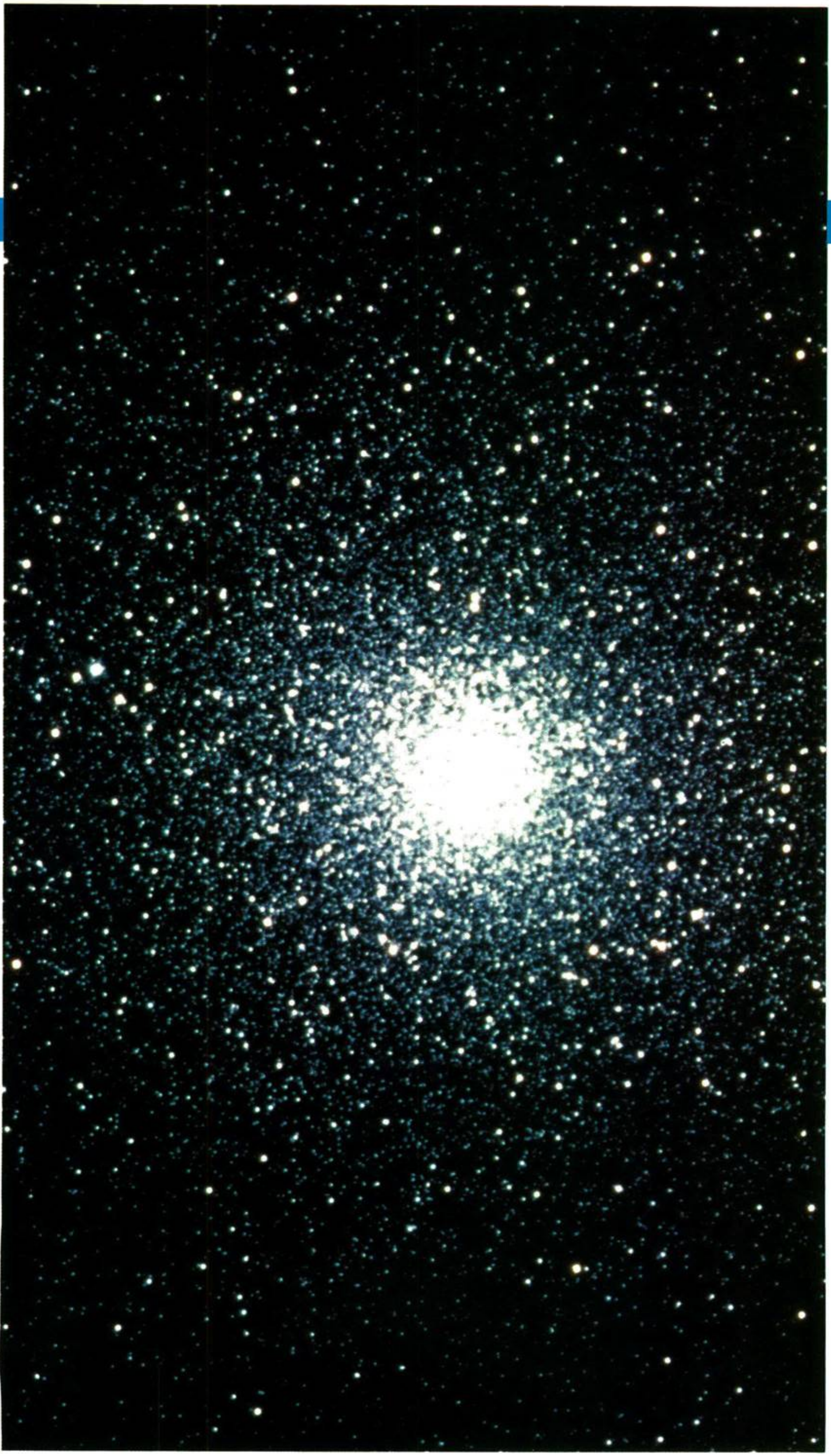
■ **Automatic-slew to any of 8,199 objects** in the CAT library.

The massive all-new Model 2600 fork mount includes an 11-inch worm gear controlled by Meade Smart Drive™ software, with achievable periodic drive errors as low as 1 arc sec. The 16″ correcting plate, of clear BK7 Grade-A optical glass, enables high UV-transmission for photoelectric photometry. The instrument is superbly suited for lunar, planetary, and deep-space photo-visual programs as well.

Suggested List Price, Base Model: $12,500. (Orders placed before 11/1/90 qualify for the special introductory price of $9,950.)

For complete information on the 16″ Meade Model 2600, please write to Meade Instruments, requesting Technical Data Sheet #2600, available at no charge.

ON THE COVER: Everybody's favorite globular cluster, M13, is perfectly placed for viewing during August. To discover how to get the best views of objects like M13, see page 66. Photo by Tony Hallas and Daphne Mount.



DENSELY PACKED WITH STARS, globular cluster M5 in Serpens is just visible to the naked eye in summer skies. Backyard telescopes show thousands of its diamond-like suns. Photo courtesy Canada-France-Hawaii Telescope Corporation.

ASTRONOMY®

August 1990

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The
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Behind the Scenes

NEW TECHNOLOGIES IN ASTRONOMY

Astronomers are ecstatic that the *Hubble Space Telescope* has at last been placed in orbit. Yet even as we wait for the arrival of the first scientific images, the first new facts, and the first new knowledge to come from them, we marvel at the new technologies that have made *HST* possible.

What a fine accomplishment! Humans have learned how to place a telescope in space, how to point it, and how to control it. We have learned how to make huge mirrors close to perfection. And we have mastered the art of making arrays of light-sensing diodes on silicon chips to capture light that has traveled the breadth of the universe. These technologies are changing the face of astronomy.

In the hobby of astronomy, too, the same technologies are making big changes. Amateurs now capture starlight with CCD chips and record celestial events on magnetic tape. Bulky television cameras have given way to 2-pound hand-held camcorders, high-tech wonders of miniaturization. At the hearts of these machines are the same sensitive CCD chips that the *Hubble Space Telescope* and the *Galileo* spacecraft, now on its way to Jupiter, use to capture their images. Within a very few years amateur astronomers will be taping deep-sky objects "live," thus bringing the thrill of amateur astronomy to ever more people.

A few hours ago, on the screen of the same computer I'm using to write this Behind the Scenes, I displayed pictures of M51, M104, and the Great Nebula in Orion. With just a few keystrokes I changed the brightness and contrast of the images, pulling out details that were difficult to see in the original. For the astronomer hobbyist with a "hacker" bent, today's CCDs are a dream come true.

On the astrophotography scene, fast color films mean shorter exposures and easier access for more hobbyists, while slower films yield crisp, bright images with professional-quality knockout color for advanced amateurs. A decade ago neither film existed — but today their use is widespread.

These new technologies mean a richer, fuller hobby and a deeper, more profound science of astronomy. At the bottom, though, the deepest satisfactions of astronomy remain unchanged. On a clear night anyone — novice, amateur, or professional astronomer — can gaze upward as the starry firmament wheels majestically overhead and see the stars as our ancestors saw them. In a moment we can experience that mingling of wonder, fear, excitement, and knowledge that only astronomy offers.

Sincerely,
Richard Berry
Richard Berry
Editor-in-Chief

ASTRONOMY

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Letters

A Close Look at Refractors

In your review of four refractors ("ASTRONOMY Tests Four Medium-Aperture Refractors", June 1990) your readers may have been led to an incorrect conclusion about the stability of the two Vixen mountings. While both are well designed, the larger DX mounting is much more stable. The damping times you reported for these mountings depend on how much weight they are carrying and how massive the tripod is. A lightweight refractor will certainly damp out more quickly than a heavier one.

After visiting telescope manufacturers in Japan last year, I was very impressed with the Vixen DX mounting and decided to use it for my small Starfire refractors. The small amplitude of its vibration particularly impressed me. When pushed or pulled, both right ascension and declination axes felt solid and smooth, with little movement due to backlash. When the telescope was slewed manually or with the drives, stars moved smoothly. Before I decided to offer this mounting, I mounted a 12cm refractor, a 3-inch guidescope, and a heavy Pentax 6x7cm camera on it and made some long-exposure photos. With 40 pounds of equipment, the mount tracked effortlessly.

Nevertheless, your article correctly pointed out some areas in need of improvement. We will seek ways to minimize the vibration settling time of the DX mount. We have also informed our Japanese suppliers that American amateurs are taller and require more tripod height on their mountings.

When evaluating optics, it would be helpful to point out some standard against which lenses should be judged. For instance, it would be useful to know that an achromat has 0.25 percent focus difference between green and violet colors. At f/15 the depth of focus is such that a violet halo of a certain size (say 10 Airy disk diameters) surrounds the image. If the focal ratio is f/7.5, the depth of focus is also reduced, thereby doubling the size of the violet halo. In order for the f/7.5 lens to have a halo 10 Airy disk diameters across, the color error must be reduced to 0.13 percent. Using this relation between focal ratios and color errors, readers could determine if a telescope has good color correction.

Although it would make life much more difficult for reviewers, telescopes should be tested for such things as light transmission of the glass, image contrast, useful high-definition fields, vi-

Genesis Owner Turned Into Zombie!

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains. What I saw there was, in many cases, better than photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

- George N. Storm, California

Photo by Jim Riffle

Unsolicited comments from warranty cards

- *It's beautiful, from case to scope.* C.C. The Netherlands
- *Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.* D.B. New Jersey
- *This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.* G.P. New Jersey
- *Very pleased with your new improvements.* J.F. California
- *Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.* W.B. Indiana
- *The telescope lives up to its expectation.* T.W. England
- *Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.* G.H. Canada
- *Sold my 8" SCT looking for better images.* P.F. New York
- *Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.* W.J. Canada
- *I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.* J.J. California
- *Beautiful equipment - Total satisfaction with first use. Keep up the good work.* M.C. Ohio
- *I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!* M.F. Florida
- *Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).* T.S. Indiana
- *Compactness & quality - a beautiful, fantastic instrument.* J.V. The Netherlands

- *It's the best 4" refractor made.* A.A. California
- *I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.* G.D. Canada
- *Genesis is the only scope in the race. I wanted the best and believe I got it.* E.S. Australia
- *As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.* R.A. Georgia
- *Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.* P.L. Massachusetts
- *The best on the market.* E.B. England
- *I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...* K.L. Texas
- *My friend borrowed it & won't give it back!!* T.L. Canada
- *I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.* P.H. Australia
- *Superior to other 4" scopes on offer.* Z.V.S. South Africa
- *Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.* W.S. Connecticut
- *I purchased this instrument because:*
  1) Apo-refractor - basic design
  2) Tele Vue reputation
  3) Dealer owns same model
  U.B. Canada
- *Genesis is as good as gold...Maybe better!* F.G. California
- *I compared specs of Tele Vue vs (other high performance refractors); T-V best choice for $.* R.A. New Hampshire
- *Magic.* C.H. England

My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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Filter set of 10 ..	159	T-adapt-std	37
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Lenshood 8"	59	T-mt.-AF	19
Lenshood 10" ...	94	Vari pol 905	49
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Nebula 2"	109	Weight set 10"	99
Nebula rear-cel	119	WFAS	119

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gnetting, ruggedness of construction, and accuracy of tracking. This would help quantify important traits of various telescopes and allow readers to make a clearer choice between various models. — *Roland Christen, president, Astro-Physics, Loves Park, Illinois*

Your review of medium-aperture refractors was generally well done and fair. However, it would have been nice to see more on the actual use and the full accessory range available for the instruments.

We noted your emphasis on color correction as a key element of optical performance, and are pleased that you found our Genesis at least equal to an f/15 doublet refractor. Our own tests and calculations place the color correction of the Genesis equivalent to an f/22 doublet, whether measured over the e-g (green/violet) wavelength range as you have done or over the more traditional d-F-C (yellow-green/blue/red) range.

As you noted, all instruments involve tradeoffs. To see a bit of color on only the brightest stars is, to us, quite acceptable given the major gains in photographic speed, wide field of view, and convenience. You might have made it clearer that our f/5 speed is 2.5 times faster than an f/8 of equivalent aperture and that the Genesis is a true flat field photographic design. The 5.4° total visual field is also 2.5 times that of an f/8. Our fluorite element is also smaller and internally sealed, minimizing any possibility of damage from dew or dust.

I'd like to address the few "con" comments in your summary. First, saying there's color in the image is misleading, as you already noted this is limited only to bright stars at high magnifications. Second, we see no negative in needing a Barlow to obtain really high magnifications since our Barlows if anything improve the image of the eyepieces. (There is an unwarranted prejudice against Barlows in some quarters.) Third, we don't provide a finder because it's not needed with low-power eyepieces. Our 55mm Plössl gives a 5.4° field at just 9x — not bad for a "finder that can't be misaligned." — *Al Nagler, president, TeleVue, Pearl River, New York*

Will We Have a Fiery Fate?

I read with great interest Daniel Whitmire and Ray Reynolds' article "Fiery Fate of the Solar System" (April 1990). In the article Whitmire states that as stars grow older they shed material, losing mass and therefore gravitational attraction. Because of this, Earth will retreat from the Sun.

In his book *Invisible Matter and the Fate of the Universe,* Barry Parker states the opposite. "It is well known that two objects orbiting one another lose energy via gravitational radiation," says Parker, "which means that an orbiting planet will slowly spiral into its star." Will Earth have a fiery fate? — *Paul D'Amico, North Providence, Rhode Island*

Editor's Note: The mass loss due to stellar evolution will have a far greater impact on the planets' orbits than the small change due to gravitational radiation.

Whitmire and Reynolds' article stated that Pluto eventually will have Sahara-like temperatures. Actually, if the Sun loses mass, Pluto will retreat outward, making Pluto's temperature reasonably comfortable. The article claims that one day Pluto will be like present-day Earth, after which Earth will resemble present-day Pluto. It's unfortunate that not one of us will be around to see such an interesting chain of events! — *James V. Blowers, Chester, Virginia*

Watch Those Airy Disks

"Test Drive Your Telescope" by Dick Suiter (May 1990) demonstrates that errors can creep into otherwise excellent articles. Suiter's table on page 58 headed "Airy Disk Sizes" gives Airy disk radii, not Airy disk diameters as the table claims. Real diffraction disks look a little fatter than the table would have you believe. In any case, on many nights clean diffraction disks will not be visible, because bumpy air smears the telescopic images. — *William R. Hamblen, Nashville, Tennessee*

Watching the Comets

In response to your article on Comet Austin ("Get Ready for Comet Austin," April 1990), I compliment you on its effectiveness and ask that you increase your coverage of other comets. This April, Comet Cernis-Kiuchi-Nakamura (1990b) and Comet Skorichenko-George (1989e_1) were both visible in small telescopes, reaching 8th and 9th magnitude. The periodic Comet Schwassmann-Wachmann 3 (1989d_1) was also visible, reaching a maximum brightness of 10th magnitude. Last January the first comet of the 1990s, Aarseth-Brewington, appeared in the evening sky and put on a tremendous

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show. In binoculars it looked like an edge-on galaxy, and in telescopes the comet resembled a miniature Comet West. — *Paul Camilleri, Victoria, Australia*

On to Mars?

I was happy to see an article on the proposed mission to Mars (Viewpoint, April 1990). The Planetary Society has been trying to push such a mission for some years now, and I was pleased to see that Bruce Murray did such a fine job of explaining the situation. Outside of the astronomical press, however, little is reported about a mission to Mars. We need to get the public involved and put aside political differences to cooperate on what would be an historic and valuable step in humanity's exploration of space. — *Caryn Swenson, Palm Bay, Florida*

Before there can be a joint U.S./U.S.S.R. mission to Mars, the two countries will have to come to agreement on the color of the planet. Although I am only a dabbler in Russian, it appears that in the advertisement for the "Red Planet Calendar" in your December issue, the Soviets consider Mars orange. — *Louis J. Lyell, Jackson, Mississippi*

Say What?

I have to take a strong stand against Mr. Dolan's opinion (April 1990). I wonder if he would like the Dutch or any other non-English-speaking people to pronounce English names according to the rules of their own pronunciation. Imagine "New York" being pronounced differently in every language. Wherever I travel, when I say New York, people know what I mean. Latin pronunciations of astronomical names form a very good means of communication between astronomers in different countries. Let them stand as they properly should. — *Rik Gruwez, Bruges, Belgium*

Remembering Starlight Nights

I just finished reading *Starlight Nights* by Leslie Peltier, a fascinating account of a man's lifelong love affair with backyard astronomy. I wish my entry into amateur astronomy had been as gentle and calculated as Peltier's was. Although I didn't pick nine hundred quarts of strawberries to buy my first telescope, I'm sure I delivered as many newspapers. *I was sorely disappointed* when my 6-inch reflector failed to provide views like those that grace your beautiful magazine. Unfortunately, I briefly lost interest in the hobby.

My affection for astronomy was rekindled several months ago and thrust forward by reading Peltier's book. I highly recommend it to anyone who needs a little inspiration from a great soul. — *Jim Muehlberg, Minneapolis, Minnesota*

Venus Versus Earth

Regarding Stephen Saunders' article, "Venus: Hellish Place Next Door" (March 1990), and particularly the question of "what went wrong" on Venus, the answer seems overwhelmingly obvious. The real difference between the two planets is the presence of life on Earth whose effects gradually modified the harsh environment of a Venus-like primitive Earth to today's aerobic, temperate conditions. — *C. Maynard Price, Pateley Bridge, North Yorkshire, England*

Amateur SETI Is Alive and Well

I feel obligated to point out a misconception in your story "Amateur SETI Project in Trouble" (Amateur News, April 1990). Bob Stephens is in no way the only amateur operating such a program, nor has he ever been. Bob Gray in Chicago, Bob Sickels in Fort Pierce, Florida, and Jeff Litchman and Gene Greneker in Atlanta, to name a few, have been doing this kind of research since Stephens was in high school.

I am an ardent supporter of Stephens' activities, but in fairness to the other active people in the field, they should be mentioned as well. — *Michael E. Valdez, vice president, Society of Amateur Radio Astronomers, Melbourne, Florida*

Trade Your Universe for Mine?

Norman Sperling's description of astronomical oxymorons (Forum, April 1990) uncovered a pet peeve of mine. The most obvious such misuse of an astronomical term is the all-too-frequent employment of *universe* as a plural noun. The only correct usage of the word *universe* refers to everything that exists, has existed, or ever will exist. Terms such as *island universe, little universe, other universes,* or *universes unto themselves* are by definition erroneous. There is only one universe! — *Alfred Gray Reid, Canterbury, Kent, England*

The problem that Sperling pointed out about the old waning Moon is easily solved by using the word *decrescent.* This is the correct word and is in the *Oxford English Dictionary.* — *Mike Feist, Portslade, East Sussex, England* ☐

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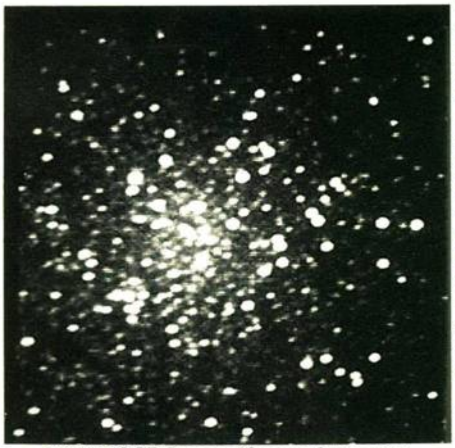

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ARE YOU A CLOSET ASTRONOMER?

by Philip M. Bagnall

I wish to confess.

Until fairly recently I was a closet astronomer. Whenever anyone asked what I did in my spare time, I would tell them I was interested in photography, heraldry, calligraphy, vexillology (go look it up) — anything. But never astronomy.

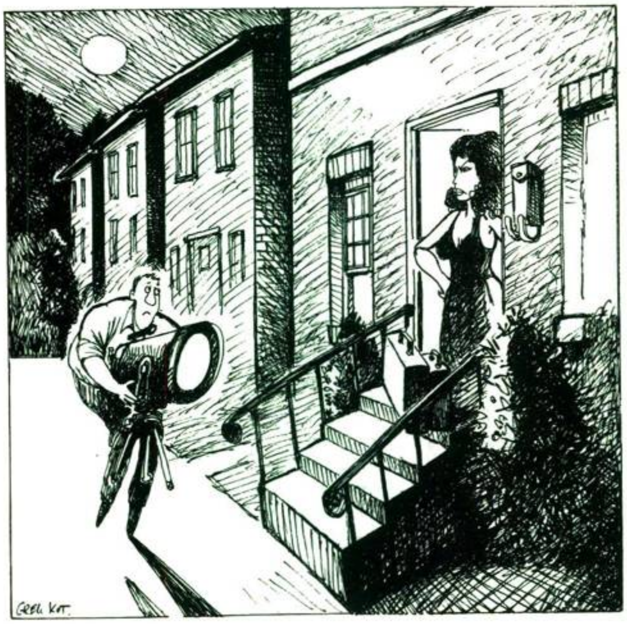
I always felt that it was something to be kept secret, like being a Freemason, or joining Greenpeace, or voting Democrat. Not that there is anything basically *wrong* with these, it's just that previous experience in admitting to my astronomical interests had taught me that the person asking would then feel obligated to ask some ridiculous question. You know the sort of thing: "Do you believe in flying saucers?" or, worse, "Can you do a horoscope for me?"

Or they would put that smug look on their face to indicate they thought I was eccentric or perhaps even a few bricks short of a full load. In a way, though, I can't really blame them. Let's face it, anyone who sits in a lawn chair through the depths of a winter's night must have something missing upstairs.

I think my problem first started to develop when I was an adolescent. I used to have nightmares about being arrested for prowling in my own back yard. I would just be lining up my telescope on some galaxy when the long arm of the law would grab me by the scruff of my neck and a thunderous voice would boom out, "'Ello, 'ello, 'ello. What 'ave we 'ere then?" — that standard phrase beloved of all British policemen. In my dream I would always turn to protest my innocence, only to find that the copper was none other than my dreaded physics teacher waving not a truncheon but a copy of Newton's *Principia*. Aargh!

When the time came to earn an honest living, I seriously considered astronomy as a career. Then I could say I was a professional astronomer, a doctor — somehow a professional astronomer would escape the problems an amateur faces. The only trouble was that astronomy exams were *hard*. Newspaper exams, by comparison, were fairly easy. They asked you only one question — "What is your name?" — and I got that right nearly 66 percent of the time. So I went into journalism instead.

For years people thought I was a high-flying socialite. I would stagger to my desk each morning, tired and bleary-eyed from a long night's observing. It took at least seven cups of black coffee before I could even begin to look at my work. Everyone thought I had been out partying all night. They would give me one of those I-know-what-you've-been-up-to winks. One elderly colleague would slap me on the back and say "Dat's mah boy!" like the dog from the Tom and Jerry cartoon. If only he knew!



One person who did know was a sales assistant in a local department store — though purely by accident. I was paying for some items at her checkout when she suddenly said, "You're an astronomer!"

"No, I'm not!" I denied vehemently.

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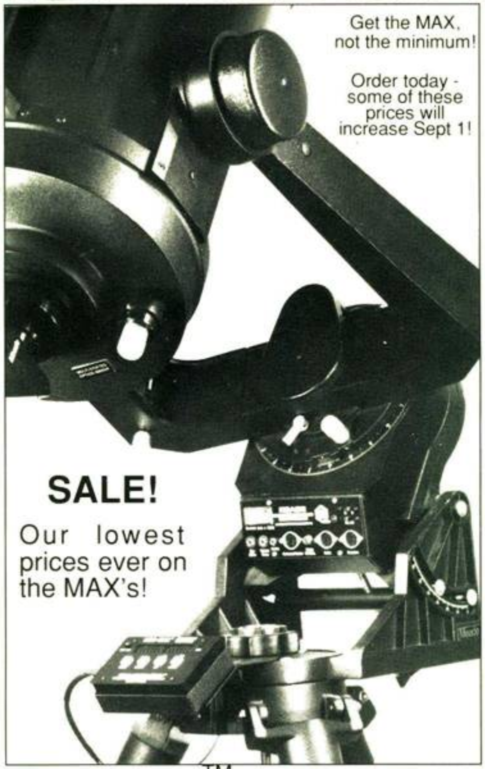

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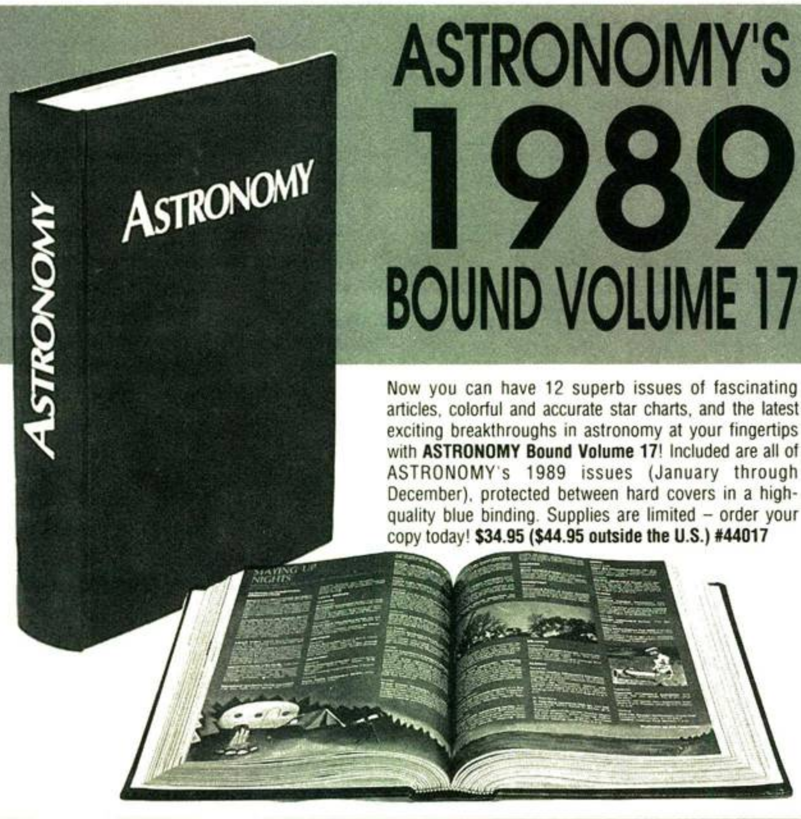

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"Oh yes, you are!" she insisted.

"Honest, I'm not. What makes you think I am?"

"You've bought a copy of ASTRONOMY," she announced triumphantly, waving the damn thing above her head for everyone to see. I left hurriedly and made arrangements to have all future issues sent to me through the mail in a *Penthouse* envelope.

For years I avoided international gatherings of amateur astronomers after a particularly nasty incident in France. I handed my passport over to the customs officer, who gave it little more than a cursory glance.

"Are you viziting Paree for buzinezz or pleazure, M'sieur?"

"Pleazure. . . er. . . pleasure," I responded.

"Aha. What sort of pleazure?" he asked, a broad grin growing across his face.

I suppose he was just trying to be polite, but I panicked. "Skiing," I blurted out.

Now in the IQ stakes this official was clearly no dummy, because he immediately realized that mountains were in short supply in Paris. I was soon carted off by the gendarme to be interrogated. Now I tried to come clean and explain that I was really attending an astronomical meeting, but it didn't work.

"You zay you ar' an astronomer? Zen tell me ze name av ze Prezidant av ze' Société Astronomique de France?"

"I don't know."

" 'Ow big eez ze telescope at Pic-du-Midi?"

"I don't know."

"When did Le Verrier die?"

"I don't know!"

"Zen tell me zees," a female officer interrupted. "I waz born on August 28. What eez my birt' sign?"

"I don't know!"

"Zen you ar' obviously not an astronomer or you would know I am a Virgo!" Her colleagues sniggered.

Twenty-four hours later I was sent back to England in disgrace.

My wife was very understanding. Indeed, it was she who encouraged me to "come out," as they say. For nearly five years after we were wed, I managed to keep my passion a secret — after all, I didn't want her to think I was some sort of weirdo. Each night, therefore, I would wait until she was sound asleep and then sneak out to the garage to set up my carefully *hidden* Schmidt-Cassegrain.

One night she must have heard me — I think it was the time I accidentally

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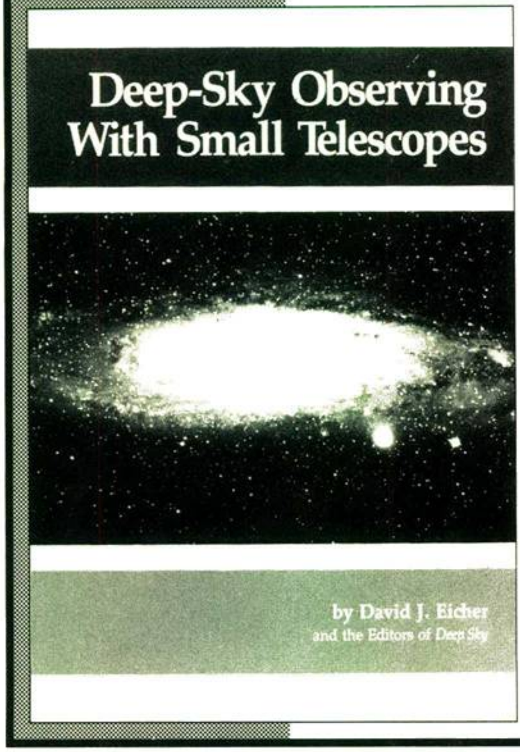

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kicked the cat — because for several weeks she kept an eye on my covert activities.

I should have realized that she was suspicious. Whenever she came across the question "Marital Status?" on a questionnaire, she would write "shaky." Finally, one morning just before dawn, I crept back into the house and there she was waiting, eyes glaring, suitcase (mine) already packed. Boy, was she relieved to find out that I was only having an affair with Venus and not Vanessa!

Anyway, she assured me that I was doing nothing wrong and pointed out all the other things people do that could be considered eccentric, like jumping out of an aircraft at 20,000 feet or dunking for hours on end a worm tied to a hook. So now I openly admit what I am and take everything in my stride.

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by Gerrit Verschuur
Astronomer and writer

Our understanding of the universe is largely determined by the theories we develop to explain observations. The continuing challenge lies in making ever tighter the correspondence between theory and reality. But at the same time it's important to remember that theory may include so many variables that a sufficiently clever person could explain virtually *anything* — even things that don't, in the end, actually exist.

This was illustrated dramatically on two recent occasions. The first concerns the pulsar discovered in supernova 1987A in January 1989. Astronomers had been searching for the newborn pulsar associated with that explosion because well-accepted theory says that pulsars are the common outcome of supernovae. Naturally, many astronomers wanted to be the first to spot the pulsar glimmering fitfully in the wreckage of the exploded star.

In due course, one team of astronomers did find a star whose brightness varied in a way that was consistent with a pulsar in a binary system, although it was spinning unprecedentedly fast and lay uncomfortably close to its companion. However, when the observers returned to make more measurements, they found no evidence of the pulsar at all.

Despite some questions about the reliability of the observations, theorists promptly offered many highly plausible explanations for the disappearance of the pulsar, why the neutron star was spinning so rapidly, and how it was possible for the object to be so close to its companion. Yet this theorizing was

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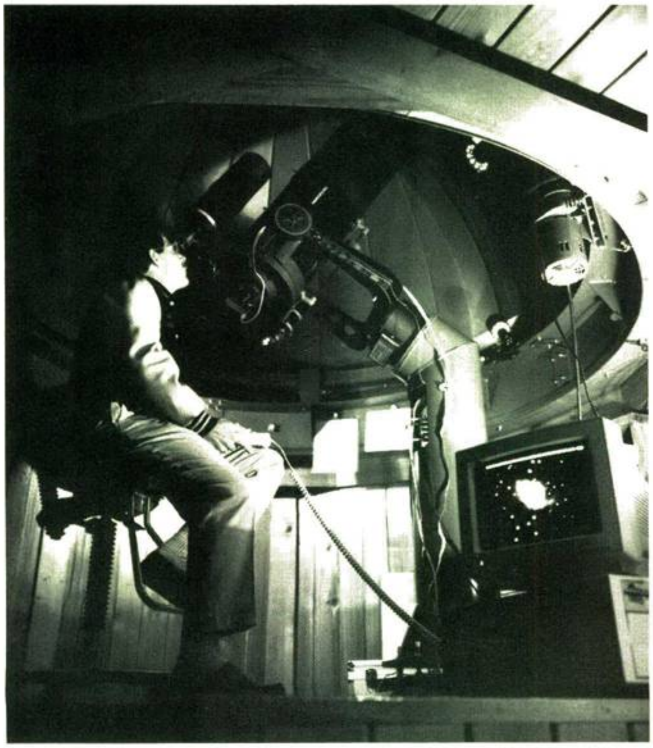

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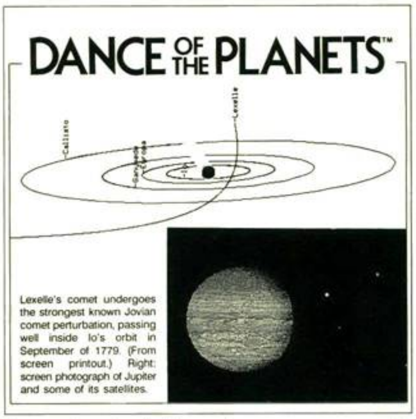

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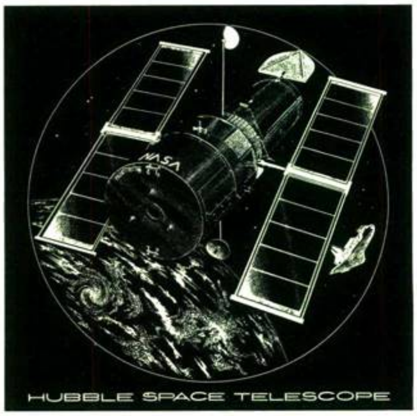

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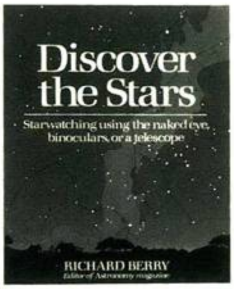

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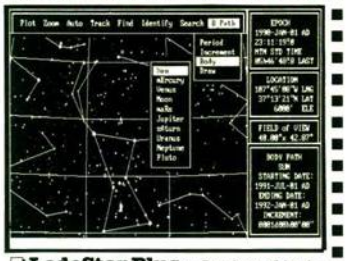

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pointless because recently the pulses were found to originate not in the supernova's stellar remnant but in the electronics of a guide camera on the telescope. (See "The Peculiar Pulsar That Wasn't," AstroNews, June 1990.)

The second example of over-optimistic theorizing involves an unexpected feature of the cosmic microwave background at submillimeter wavelengths. Some observers had claimed to observe a pattern in the spectrum of the cosmic microwave background that was inconsistent with the traditional explanation involving the Big Bang. The possibility of an instrumental effect was considered but rejected.

After the feature was noticed, elegant explanations were offered by various theorists, the latest being one that showed an especially close fit between the data and the theory.

Ironically, due to delays in publishing, this work appeared in print nearly two months *after* instruments on board the *Cosmic Background Explorer* satellite — which was designed to study this radiation in great detail — found no evidence whatever for the signal the theory so elegantly explained. While this surprised few observers, it highlights the fact that one can account for anything by invoking complex interaction of natural processes.

The question running through my mind is, If theoreticians can account for virtually anything, how can we trust them — even when they deal with phenomena that are reliably observed? Given that human beings are adept at "explaining away" any new phenomenon, whether or not it has any relation to reality, it's also worth considering another matter. A colleague once pointed out that even if we were to detect a radio signal from an extraterrestrial civilization, we might never realize it because theoreticians would soon provide elegant *natural* explanations for it! In fact, how long would we persist in refining theories before we gave up and considered an artificial cause?

These cases exemplify a "cleverness" problem many scientists may prefer not to think about. Theories stand or fall by the observational data they explain. Therefore, given that we know our data are limited, why do so many astronomers place so much emphasis on theory over data? And is it really too much to expect us to transcend clever and beautiful theories or beliefs if they stand in the way of seeing the universe more clearly?

An uncomfortable feeling remains with me that we often get so carried away by our theories that we forget that even the best of them may have little to do with reality. While the ideal image of the scientist is that he or she is above such self-delusion, these recent cases remind me at least that often we are still prisoners of the way we habitually think. ☐

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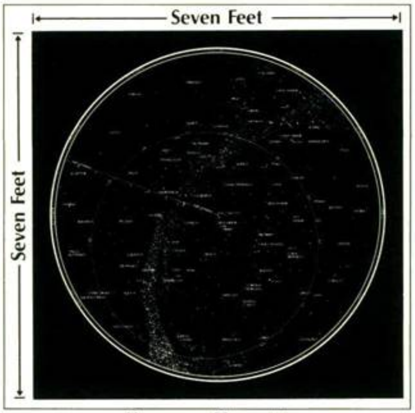

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► *(Top right) Ultima Series Eyepieces. (Bottom left) Ultima eyepiece shown with standard eyecup.*

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93351	7.5 mm	5	51°	1¼″	5.3 mm	yes
93352	12.5 mm	5	51°	1¼″	9.0 mm	yes
93353	18 mm	5	51°	1¼″	12.9 mm	yes
93354	24 mm	5	51°	1¼″	17.9 mm	yes
93349	30 mm	5	50°	1¼″	20.6 mm	yes
93355	35 mm	5	49°	1¼″	24.9 mm	no
93356	42 mm	5	36°	1¼″	31.7 mm	no
93357	15 mm-WA	7	70°	1¼″	7.2 mm	yes
93358	19 mm-WA	7	70°	1¼″	9.5 mm	yes
93359	23 mm-WA	7	69°	1¼″	9.5 mm	yes
93360	45 mm	5	50°	2″	32.1 mm	no
93361	60 mm	5	45°	2″	39.2 mm	no
93362	80 mm	4	34°	2″	50.3 mm	no

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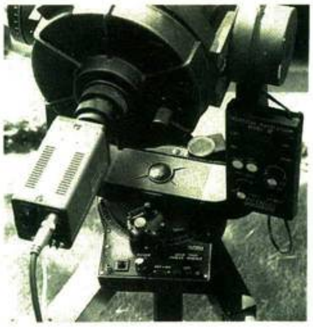

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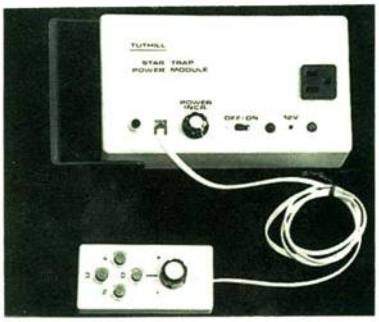

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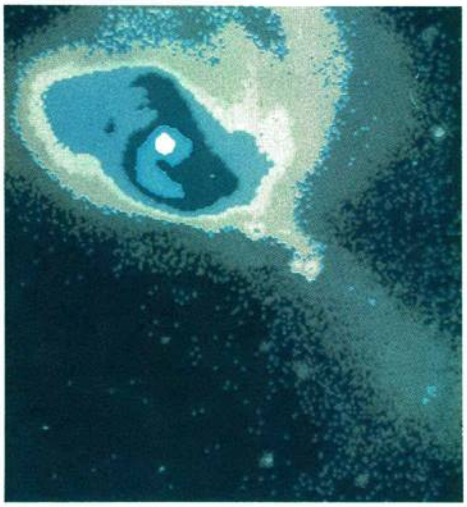
AN ALMOST SWITCHED-ON GALAXY

How can you tell whether a galaxy is turned on or not? A team of astronomers set out to answer that question by making a series of detailed radio, infrared, optical, and spectroscopic observations of an unusual spiral galaxy in Eridanus.

The observations were conducted by Susan G. Neff of Goddard Space Flight Center, John B. Hutchings of the Dominion Astrophysical Observatory, S. Adam Stanford of the University of Wisconsin's Washburn Observatory, and S. W. Unger of the Royal Greenwich Observatory, Herstmonceux, England. Their evidence suggests that the nucleus of NGC 1614, which is quiet now, may eventually become active.



NGC 1614'S UNUSUAL SHAPE is probably the result of a galaxy merger. The "tail" (the feature extending to the lower left) contains bright knots that may be remnants of the companion. The nucleus has a Seyfert-like luminosity but is not yet active. Photo courtesy of Susan Neff, Goddard Space Flight Center.

One of the important tasks in studying galaxies is to see if an evolutionary thread exists between galaxies of different energies. Most galaxies are "normal" in that they have symmetrical shapes and don't emit more energy than can be accounted for by their individual stars. A small percentage of galaxies, however, emit unusually large amounts of energy. At the most energetic end of this class of active galaxies are quasars, which are very bright optically but are even brighter at ultraviolet wavelengths. Some quasars also emit excessive infrared radiation, which is thought to be from dust that is re-emitting radiation absorbed at shorter wavelengths.

Less energetic are the Seyfert galaxies, named for the American astronomer Carl Seyfert who first described them in 1943. Seyferts are, in some respects, "scaled-down" versions of quasars. Spectroscopic observations of Seyferts indicate the presence of very hot, expanding gas in a compact nuclear region.

In addition to their prodigious energies, active galaxies often exhibit distorted features, such as misshapen spiral arms and tails or plumes of ejected gas. Without question, the outer structure of NGC 1614 is clearly disturbed. Infrared and optical photographs show a large curved extension of one of the spiral arms, extended spiral arms to the east of the nucleus, a long linear tail to the south, and bright knots in the tail. Neff said that the tail, knots, and extended arms are probably the remains of an interacting companion galaxy.

But is this galaxy active? At longer wavelengths, the nuclear region of NGC 1614 becomes increasingly brighter. In fact, at far-infrared wavelengths, the luminosity is the same as that for Type I Seyfert galaxies, whose spectra most resemble quasars. The high infrared luminosity of the central region may be due to a massive burst of star formation embedded in dust. But no Seyfert-like nucleus is currently seen in the system. Either the nucleus has not been activated yet or its radiation cannot directly escape the dust.

Based on these and other observations, the astronomers conclude that NGC 1614 may be poised between the ultraluminous infrared stage and the active stage. In a few million years, said Neff, an active nucleus may appear.

Neff and her colleagues suggest that a detailed study of a larger sample of these almost-active galaxies is needed. To understand how active galaxies evolve, it is important to determine how many galaxies do and do not form an active nucleus and to compare these to the number of active galaxies in the local universe. Such knowledge would go a long way toward helping astronomers understand the evolution of galaxies in general.

FAINTEST "STAR" COULD BE A BROWN DWARF

An extraordinarily faint object discovered recently in the southern sky may be a long sought after brown dwarf. Astronomers have spent years searching for brown dwarfs, objects that condense out of interstellar clouds like stars do but are not massive enough to ignite the thermonuclear reactions that make stars shine. If star formation theories are correct, brown dwarfs may be the most common objects in the universe and could make up a significant fraction of the universe's mass. Despite tantalizing evidence, however, there is no observational proof of brown dwarfs. (See "Do Brown Dwarfs Really Exist?" by Deborah Byrd, April 1989.)

This newest and very promising brown dwarf candidate was first detected in 1988 by Mike Hawkins of the Royal Observatory in Edinburgh, Scotland. While searching for very red stars on Schmidt plates taken at Australia's Siding Spring Observatory, Hawkins identified a very faint and very red object near the borders of the constellations Grus, Microscopium, and Indus. He singled the object out as a possible brown dwarf because brown dwarfs radiate little energy and appear red because they are cool.

Following this discovery Phillip Ianna of the University of Virginia and Mike Bessell of Mount Stromlo and Siding Spring Observatories in Australia observed the object over the past two years. During that period they have seen it change position relative to more distant stars, reflecting Earth's orbital motion around the Sun. From this observed displacement the researchers calculate that the object is 68 light-years away.

Using this distance and the object's apparent brightness, the astronomers were then able to derive the object's absolute luminosity. What they found was a total surprise: the object turned out to be the faintest stellar object ever seen. It shines only 1/4,000 as brightly as the Sun does and is some 30 percent fainter than the previous faintest "star."

This low luminosity was a strong clue that the object might be a brown dwarf. Because brown dwarfs cannot sustain nuclear reactions in their cores, they shine mostly from energy generated by gravitational contraction. This is a relatively inefficient energy source, however, so brown dwarfs should have very low luminosities.

But just because an object is faint, cool, and red does not guarantee that it is a brown dwarf. The final step before confirming that conclusion is determining the object's mass. An object larger than about 8 percent of the Sun's mass (eighty times the mass of Jupiter) is massive enough to initiate nuclear reactions; a smaller object is not.

The researchers estimate that the new brown dwarf candidate has a mass of about 5 percent that of the Sun, which would place it firmly in the brown dwarf category. But to confirm that figure they need to know the object's age as well as its luminosity, because a brown dwarf fades rapidly as it grows older. Early indications are that the object belongs to a population of young stars in the disk of the Milky Way and thus is unlikely to be more massive than 8 percent the mass of the Sun. The observations are not yet definitive.

Ianna and Bessell are continuing to observe both this object and other faint red stars. They hope that such detailed observational studies will help astronomers better understand the fundamental characteristics of brown dwarfs.

ANTARCTIC METEORITE IS A SAMPLE OF LUNAR MARE

To date scientists have identified four or five meteorites found on the Antarctic ice cap as being chunks of the

Amateur News

ASTEROIDS NAMED FOR ASTRONOMY EDITORS

In May the International Astronomical Union honored two ASTRONOMY editors and one ASTRONOMY columnist by adopting their names for previously-unnamed minor planets. The permanent name 3684 Berry replaced the temporary designation 1983 AK, for ASTRONOMY's Editor-in-Chief Richard Berry. The permanent name 3617 Eicher replaced 1984 LJ, for Assistant Editor David J. Eicher. The permanent name 3505 Byrd replaced 1983 AM, for ASTRONOMY's Deborah Byrd, who writes the magazine's "Eye on the Sky" column each month.

The asteroids were discovered at the Anderson Mesa Station of Lowell Observatory in Flagstaff, Arizona, by astronomer Brian Skiff. The following citations, prepared by astronomers Skiff, David H. Levy, and Stephen J. Edberg, appeared in the *Minor Planet Circulars* this summer.

3684 Berry. Named in honor of Richard Berry, since 1979 Editor-in-Chief of ASTRONOMY magazine. He has actively promoted amateur astronomy by means of books on beginning astronomy and telescope making as well as editorship of the technical journal *Telescope Making.* He was also a pioneer in increasing awareness of light pollution by mapping its extent in southern Ontario, Canada, in the 1970s.

3617 Eicher. Named in honor of David J. Eicher, founder and Editor-in-Chief of *Deep Sky* magazine. In June 1977, as a high school student, Eicher began *Deep Sky Monthly,* designed to promote amateur deep-sky observing. After more than fifty issues, the monthly became a quarterly in 1982 and Eicher became an Assistant Editor of ASTRONOMY magazine. Through his magazine and two books on viewing, Eicher has worked tirelessly to encourage amateur astronomers to make high-quality observations of galaxies, clusters, and nebulae.

3505 Byrd. Named in honor of Deborah Byrd, writer and producer of "Star Date," a radio program that since 1978 has broadcast astronomical news and information over several hundred stations in the United States. Byrd began her career providing public information via telephone messages and brochures for the University of Texas McDonald Observatory. This has progressed to include the popular radio program, a series of brief spots for television, and more extensive writing for magazines such as *Physics Today, Highlights for Children,* ASTRONOMY, and *Sky & Telescope.* In 1979 she founded the Texas Star Party, now one of the largest meetings for amateur astronomers in North America, which takes place each year near McDonald Observatory in west Texas.

HUBBLE SPACE TELESCOPE AMATEUR PROPOSALS: ROUND TWO

In May the Hubble Space Telescope Amateur Astronomers Working Group announced the opening of round two of amateur proposals for observing time on the *Hubble Space Telescope.* The program is open to all U.S. citizens who do not have an advanced degree in astronomy. Applications to use *Hubble* for amateur observing projects may be made until November 1, 1990.

"The proposals should emphasize the use of *Hubble's* unique capabilities," said Stephen J. Edberg, chairman of the Amateur Working Group. "Primary among the instrument's attributes are high resolution, an extended spectral range, and superior sensitivity. Amateurs should remember that only research proposals that *cannot* be done from the ground will be considered."

The Working Group consists of members from the American Association of Variable Star Observers, the Association of Lunar and Planetary Observers, the Astronomical League, International Amateur Professional Photoelectric Photometry, the International Occultation Timing Association, and the Western Amateur Astronomers. By mid-1991 the group will recommend proposals and selection criteria for consideration by Space Telescope Science Institute director Riccardo Giacconi.

Interested persons should submit a letter to Round Two HST Proposals, American Association of Variable Star Observers, 25 Birch Street, Cambridge, MA 02138. By return mail requestors will receive information on the *Hubble* telescope, proposal forms, and entry instructions. Completed proposals must be postmarked no later than November 1, 1990.

Space News

FIRE STREAKED THE NIGHT above Hawaii as *Discovery's* external tank reentered April 24 on the mission that launched Hubble. Photos by William Albrecht.

Moon. But all of them seem to have come from the lunar highlands, the light-colored regions that cover some 70 percent of the Moon's visible side and about 98 percent of its farside.

Writing in the December 21/28, 1989, issue of *Nature*, Rutgers University scientist Jeremy S. Delaney announced that an Antarctic meteorite from the Elephant Moraine region (code named EET87521), which had previously been classified as a brecciated eucrite from the asteroid belt, is in fact a brecciated basalt from one of the lunar maria. This makes it the first known mare sample to reach Earth as a meteorite.

Delaney bases his reclassification on a careful reanalysis of the meteorite's composition. This revealed a very low titanium content in the basalt and a bulk composition closely resembling the mare basalt samples brought back by *Apollo 17* and *Luna 24*. The meteorite's oxygen-18/oxygen-17 isotope ratio is also near the lunar value. (Oxygen isotope ratios are important tracers of rock origins since they appear to differ individually for each "parent object" in the solar system, such as a planet, asteroid, or moon.) Last, the meteorite's rock fabric shows ample evidence in the form of glass and high-pressure minerals that it was shocked by impacts in a way that is consistent with a mare basalt.

Delaney notes that this new finding means that the Antarctic/lunar meteorites now on hand sample both known varieties of lunar crust and thus form a valuable resource, even if their exact source locations are not known. He also points out that although the numbers are small, simple statistics indicate that two or three of the highland meteorites should have come from lunar farside sites. If these meteorites can be isolated from the others, scientists will have their first looks at lunar territory that is almost wholly unknown and which has been observed only from orbit.

COMET MACHHOLZ HAS AN UNUSUAL EVOLVING ORBIT

Periodic Comet Machholz (1986 VIII) has been found to have an unusual orbit that is evolving on an astronomically rapid timescale. Discovered in May 1986 at 10th magnitude by amateur astronomer Donald Machholz, who was using 29x130 binoculars, the comet was past perihelion and fading swiftly. By late June 1986 it had dropped to about visual magnitude 13 and was last observed in early September that year at magnitude 19.5.

Recent studies of its orbital evolution by Daniel Green of the Harvard-Smithsonian Center for Astrophysics and several coworkers have been published in *Science* (March 2, 1990). Comet Machholz has a 60° orbital inclination and a period of 5.25 years. It passes closer to the Sun at perihelion — 0.127 astronomical unit, or 19 million kilometers — than any other known comet with a period under 150 years. The comet's high inclination has kept it at least half an astronomical unit away from Jupiter's perturbing gravity for the past several thousand years, even though the comet's aphelion distance (5.9 AU) lies beyond Jupiter's orbit (5.2 AU).

The studies by Green and his associates show that Comet Machholz' perihelion distance has been diminishing for the past several centuries and will continue to shrink, reaching a minimum value of 0.03 AU (4.5 million kilometers) by about the year 2450. Thereafter perihelion distance will begin to increase again.

Green's team found that over an approximate 4,000-year period the comet's perihelion distance changes rhythmically between 0.03 AU and almost 1.0 AU. They stressed, however, that their calculations ignore all orbital changes from jetting activity by the comet nucleus, which is likely to occur. Yet they feel the results will hold generally true.

A major question for comet scientists is how well the comet's nucleus will fare under the intense solar radiation encountered at perihelion. Green points out that Machholz is ideal to monitor for physical changes at each perihelion. Moreover, the comet is observable in large instruments even while near aphelion, which last occurred in December 1988. University of Hawaii astronomer Karen Meech detected it at 22.5 magnitude with a 1.5-meter telescope at Cerro Tololo Observatory in Chile in April 1989 and at 21.8 magnitude in June 1989.

Given its short orbital period, Machholz will soon be back. Its next perihelion is July 22, 1991. Because of its steep orbital inclination, Machholz approaches perihelion from far southern declinations. Therefore it will be visible to Southern Hemisphere observers at a visual magnitude of 11 to 13 for a month or so before perihelion, and visible to Northern Hemisphere observers during the month or two afterward. □

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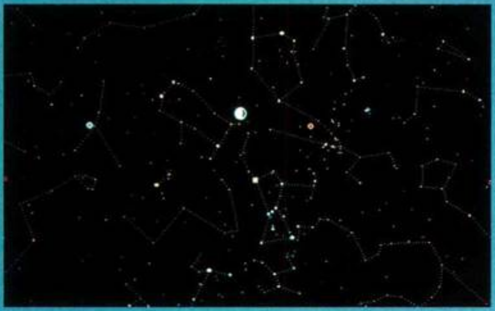

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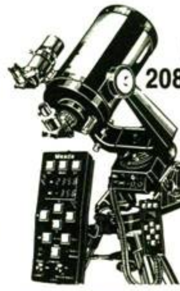

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Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
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LUMICON 1.8x multiplier lens	**$235.00**

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1¼" right-angle version, w/star diagonal	**$209**
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1¼" Amici Prism diag. for correct left-right views	**$69.50**

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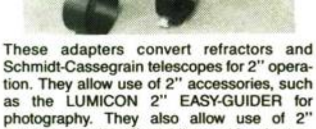

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LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

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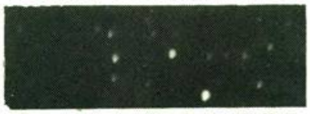

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

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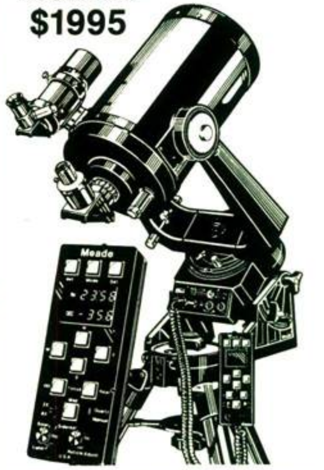

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LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

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MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

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Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

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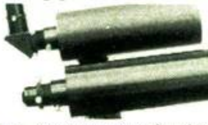
Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion low profile focuser	**$129.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



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1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle version, w/star diagonal	**$195**
1¼" Deluxe right-angle Super-Finder*	**$279**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$159**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

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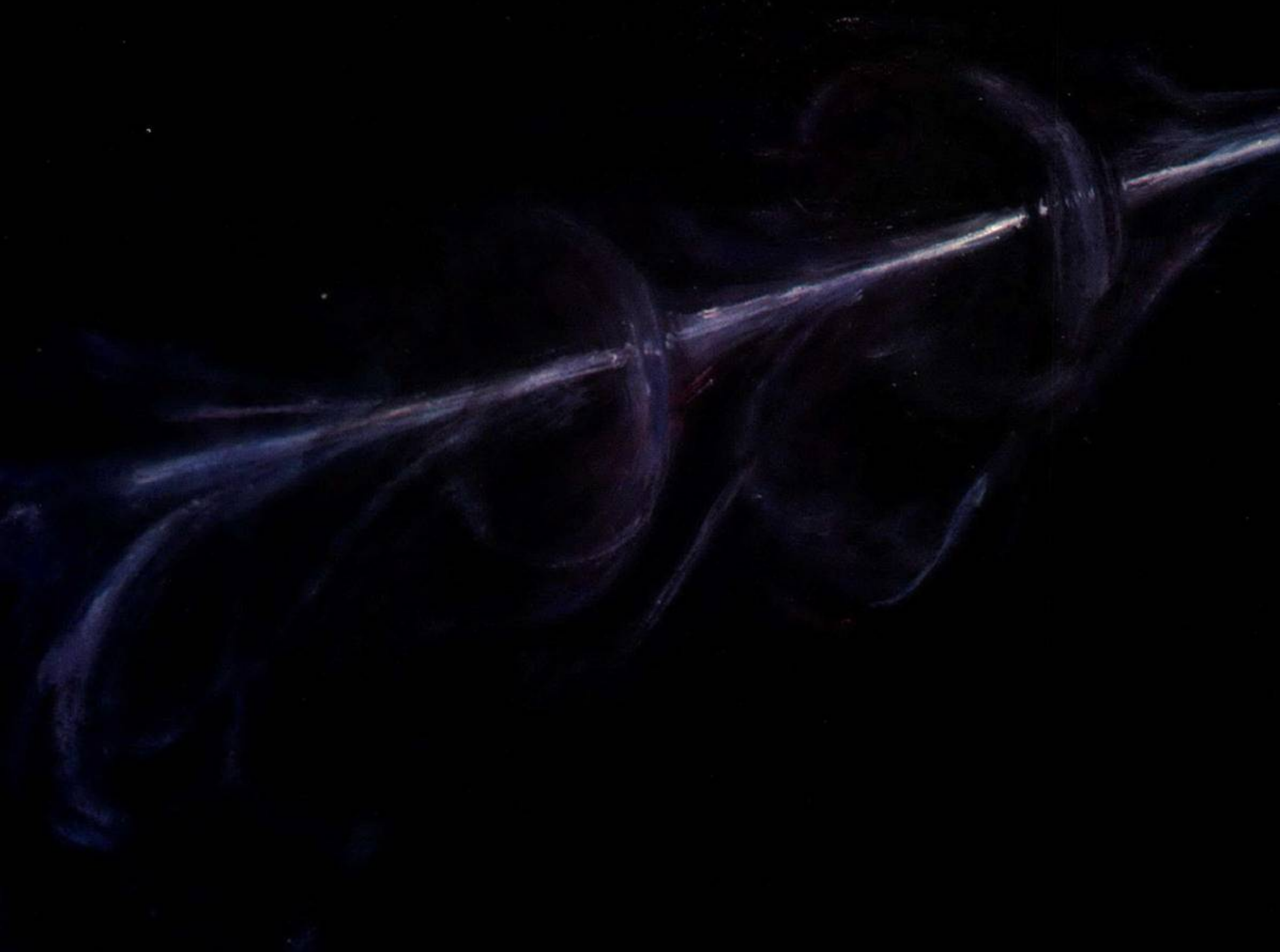


FROM TAIL TO HEAD, the view along a cosmic jet back toward the nucleus of an active galaxy. Painting by Thomas L. Hunt.

Chasing the Monster's Tail: New Views of Cosmic Jets

Radio telescopes and supercomputers are working together to reveal new features in the mysterious jets of gas emanating from the cores of active galaxies and quasars.

by Jack O. Burns

Within the last decade astronomers have been able to view active galaxies and quasars in ever-increasing detail. Whereas only the most obvious features are visible with optical telescopes, data collected by radio telescopes, such as the Very Large Array (VLA) in New Mexico, have allowed astronomers to produce images of these energetic objects at longer, more telling wavelengths.

By far the most intriguing structures seen in some of these images are cosmic jets — streams of high-energy particles that spew out of the nuclei of active galaxies and quasars and stretch for tens of thousands of light-years out to giant diffuse lobes or "tails." Sensitive radio maps of these intriguing features reveal complex knots, filaments, and loops embedded within the jets and lobes. Moreover, they show that cosmic jets come in a variety of different shapes, which some astronomers think may be due, in part, to the interaction of the jet's high-velocity gas with the intergalactic environment.

Just as observing a river from the banks reveals little useful information about the river's source, history, and hydrodynamics, observations of cosmic jets can't tell astronomers what the nature of these structures are or how they form and evolve. Recent advances in computer software and hardware, however, have allowed astronomers not only to construct very high-contrast images of jets, but to model their behavior as well. This synergistic relationship has opened the door to new and exciting theoretical insights. Using supercomputers, astronomers are now able to numerically simulate the development of radio jets as they propagate from the cores of galaxies into the intergalactic medium. The results of the simulation's calculations are then converted into radio emission images that can be directly compared with VLA maps of the real thing. For the first time, astronomers can test theoretical models directly against real radio data with comparable resolution and contrast.

Feeding the Monster

Only a few percent of all galaxies and quasars are sources of extended radio emission. Yet these objects intrigue astronomers because of their structural beauty, their power, and the exotic mechanism that fuels the radio sources in their cores. These relatively rare beasts spawn giant lobes of radio emission with enough energy to equal or exceed that from the hundreds of billions of stars within the galaxy or quasar. The engines that drive these radio sources are probably giant black holes with masses ranging from 10 million to a billion suns.

A black hole is the favorite candidate for the "monster" at the core of radio galaxies and quasars because it is highly efficient in converting matter into energy. The strong gravitational field of a black hole accelerates and heats the gas that falls onto a flattened accretion disk swirling around the rotating hole. The energy and high-speed electrons, in the form of jets, are then redirected back out along the magnetic field lines of the black hole's north and south magnetic poles, a direction that is perpendicular to the accretion disk. The jets are simply blown out of the galaxy/quasar core along the direction of least resistance by the heat and strong electromagnetic dynamo action of the accretion disk.

Astronomers still can't explain why so few galaxies and quasars are radio sources. Recent optical observations, however, indicate that a fairly high percentage of radio galaxies and radio quasars are "disturbed" in appearance — the optical images show filaments, plumes, or tidal tails. These features are indicative of recent gravitational interactions with nearby companion galaxies. Such tidal encounters could seriously stir up the inner cores of galaxies, forcing fresh gas or disrupted stars onto the accretion disks of black holes. This mechanism may provide the fuel needed to power the radio source.

Classes of Radio Sources

In the mid-1970s, B. L. Fanaroff and J. M. Riley from Cambridge University recognized that extragalactic radio sources could be divided into two classes according to their power, or energy output, and structure.

Class I radio sources are weak in terms of total radio luminosity, but their jets have complex forms and structures, something that extragalactic astronomers refer to as morphology. These sources are almost always associated with galaxies rather than quasars. Generally, Class I sources are elongated and their radio emission diminishes in intensity with distance from the radio galaxy. They often have two jets that emerge in opposite directions from the galaxy core.

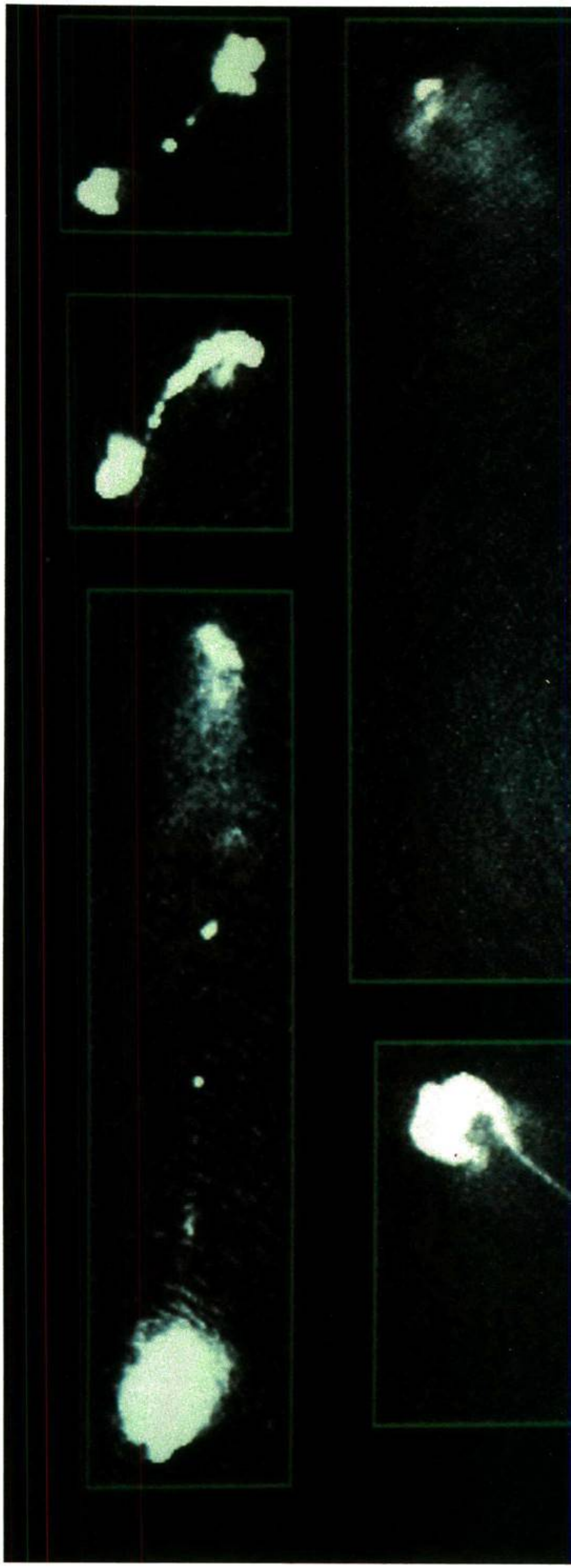
For some Class I radio galaxies that are located in clusters, the jets are bent into spectacular U-shaped structures that eventually flare into diffuse "tails." These galaxies are referred to as head-tail sources — the head being the galaxy, the tails being the radio-emitting lobes fed by jets. The bend in the jet is produced by the radio galaxy's rapid motion (sometimes thousands of kilometers per second) through a hot, dense intracluster medium, whose presence is known via its x-ray emission. The tails are swept back behind the radio galaxy by the dynamic pressure imposed by this medium, much like the pressure of the wind against cigarette smoke blown from a moving automobile.

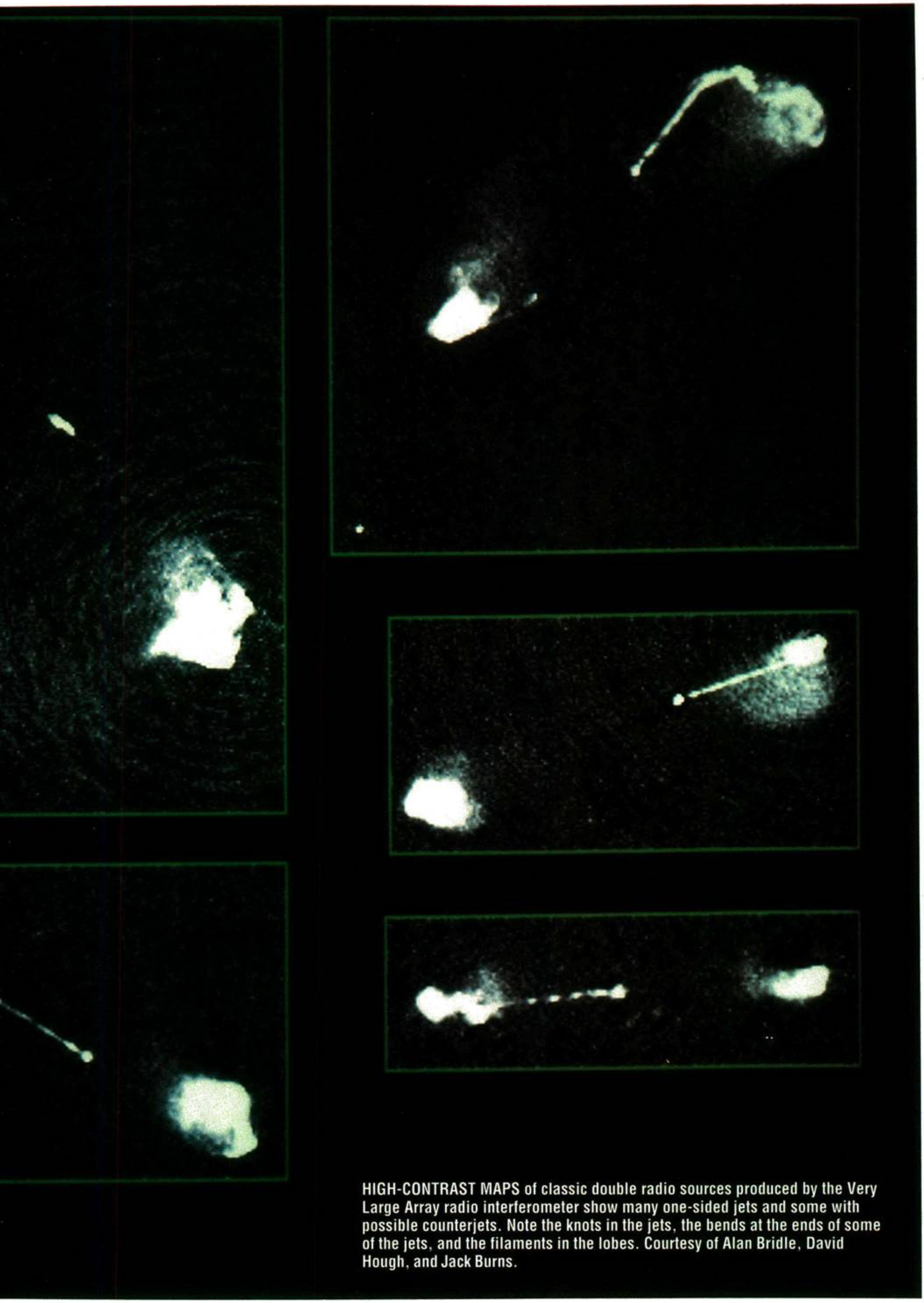
Class II sources are the most powerful. They generally are referred to as "classical doubles," because a compact core, coincident with the nucleus of the galaxy or quasar, lies midway between two lobes of strong radio emission. The radio surface brightness peaks at "hot spots" located at the extremities of the lobes. A single jet is most often found emanating from the core of Class II sources "feeding" into what is generally the brightest and most compact hot spot in one of the lobes.

The Structure of Classical Doubles

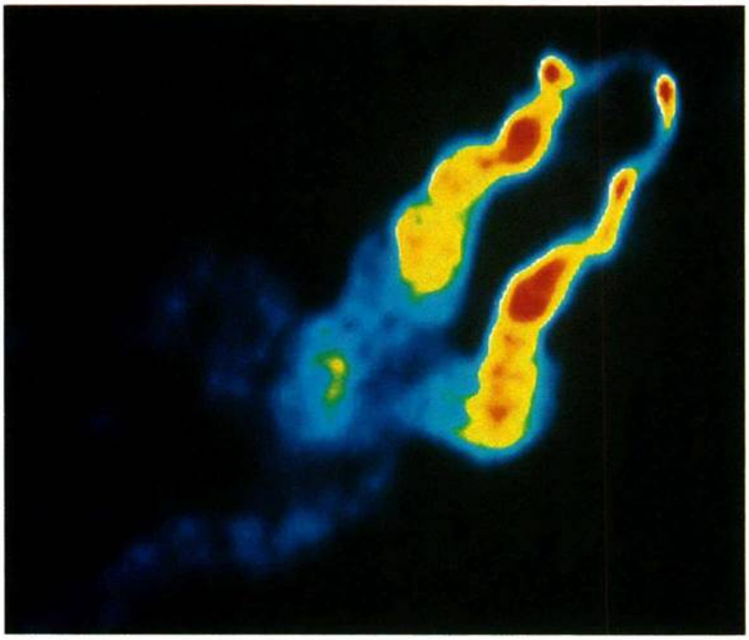
For nearly a decade, astronomers have been puzzled by the fact that classical doubles exhibit only one-sided jets. One model that explains this jet asymmetry assumes that each of the lobes is powered by a jet, but we can only see the jet that is moving in our direction. The gas or plasma in the jet is presumed to be moving very close to the speed of light. The special theory of relativity predicts that the jet pointing toward us will be boosted in intensity and the counterjet pointing away will be diminished by the same factor. Thus, relativistic effects cause one jet to appear much brighter than the other. In principle, if astronomers could produce even more sensitive maps, we would begin to see the dimmer counterjet. Recent high-contrast VLA maps are revealing possible pieces but no complete counterjets yet.

In 1974, Roger Blandford and Martin Rees from Cambridge University proposed a "twin-exhaust" jet





HIGH-CONTRAST MAPS of classic double radio sources produced by the Very Large Array radio interferometer show many one-sided jets and some with possible counterjets. Note the knots in the jets, the bends at the ends of some of the jets, and the filaments in the lobes. Courtesy of Alan Bridle, David Hough, and Jack Burns.



HEAD-TAIL RADIO SOURCE 3C 129 exhibits a distinctive U-shaped structure. The galaxy ("head") is located near the lower left at the base of the jets. Two jets emerge from the galaxy core and are blown back into diffuse "tails" by the rapid motion of the galaxy through the intergalactic medium. Courtesy of Larry Rudnick and Jack Burns.

model to explain the basic morphology of classical double sources. (This model is particularly noteworthy since it predicted the existence of jets before they were discovered with radio interferometers.) Blandford and Rees speculated that thin, narrowly-focused, fluid-like beams or jets born near the central galaxy/quasar engine are driven outward by the kinetic energy of the plasma beam — much like the exhaust from a supersonic aircraft. At the outer, leading end of the jet, called the working surface, a strong shock forms as the jet's plasma pushes into the surrounding medium, causing the jet material to rebound toward the galaxy by "ram" pressure. Blandford and Rees interpreted the hot spots in classical doubles as the shocks at the working surface of the jets, and the lobes as the diffuse jet material blown back by the intergalactic wind.

By the early 1980s, supercomputer simulations by astronomers Michael Norman, Karl-Heinz Winkler, and Larry Smarr, using a Cray computer at the Max Planck Institute in West Germany, verified and significantly expanded upon the Blandford-Rees model. These and subsequent simulations used the basic equations of fluid dynamics to follow the evolution of a cylindrical jet out of a galaxy core and into the intergalactic medium. From these studies, astronomers have concluded that two key parameters appear to affect the structure of the classical doubles: the velocity of the jet in terms of its Mach number (a measure of how many times the jet velocity exceeds the speed of sound in the jet gas) and the ratio of the jet's gas density to that of the intergalactic medium.

It appears that the jets in classical doubles are highly supersonic, with Mach numbers of 10 or greater, and that the jet plasma is light (that is, less dense than the surrounding medium). In the weaker but more complicated Class I sources, the radio plasma also appears to be less dense than the surrounding gas, but the jets are only mildly supersonic (Mach numbers of 2 to 5) and the tails are subsonic. Supercomputer simulations of such jets reproduce both their overall shape and many of the detailed structures seen in recent VLA maps.

Numerical Observations

Over the past five years, the creation of several national supercomputing centers by the National Science Foundation has allowed these types of simulations to be run in the United States. Michael Norman, now at the National Center for Supercomputing Applications at the University of Illinois, and I, along with students and postdoctoral fellows, have formed a unique collaboration to study both the observational and theoretical aspects of radio jets using Cray computers.

But a powerful supercomputer alone is not enough to model these extended radio sources. The computer must be programmed with the basic laws of physics, and sophisticated schemes must be developed that allow jets to evolve in time within the confines of these laws. The computer program that we run at the University of Illinois — called ZEUS — was written over a period of more than a decade. The basic design of the code began with the supercomputer pioneer James Wilson at the Lawrence Livermore Laboratory. For his Ph.D. dissertation Norman adapted the program to investigate cloud collapse and star formation. Later at the Max Planck Institute in West Germany, Norman, Winkler, and Smarr expanded the program to model the extragalactic jets that had recently been observed in great detail with the VLA. Students and postdocs have continued to rewrite and advance ZEUS, which now has more than 25,000 lines of computer code.

A hydrodynamics program such as ZEUS begins with the equations for a compressible gas or fluid, which were originally derived by the brilliant Swiss mathematician Leonhard Euler in 1755. It took the invention of sophisticated, large-memory computers, however, before the full potential of these equations could be exploited. ZEUS calculates the time-dependent flow of a cylindrical jet on a numerical grid. At each time step, ZEUS updates the hydrodynamic variables of density, pressure, and entropy (a measure of disorder in the system) according to Euler's equations. By solving Euler's equations in this fashion, astronomers and physicists can reproduce the complex and chaotic structures that are viewed in nature — such as the turbulence seen behind a motorboat and the instabilities in a wiggling firehose. The complex, nonlinear process inherent in Euler's equations can only be extracted and tracked using numerical techniques and a large computer.

For his Ph.D. dissertation, David Clarke significantly extended ZEUS by including magnetic fields in the calculations. This allowed us, for the first time, to produce maps of radio emission similar to those obtained by the VLA. (The radio emission observed from jet sources in galaxies and quasars is generated by fast electrons spiraling in magnetic fields, a process termed synchrotron radiation.) These "numerical observations" have placed supercomputer models onto the same footing as VLA observations where we can directly compare emissions, and thereby probe the underlying physics in unprecedented detail.

One new result from our numerical observations is that jets with very strong magnetic fields tend to produce lobeless sources. Magnetic forces accelerate jet plasma beyond the head of a hydrodynamic jet into a thin "nose cone" structure. Such sources do not have flow-back material or cocoons. There are a few quasars, such as 3C 273, that appear to have nose cones without cocoons, but such structures are rare. My colleagues and I have concluded that magnetic fields do not play a dominant role in forming the structure of classical double sources — a finding that was only possible using the supercomputer.

Born-Again Radio Jets

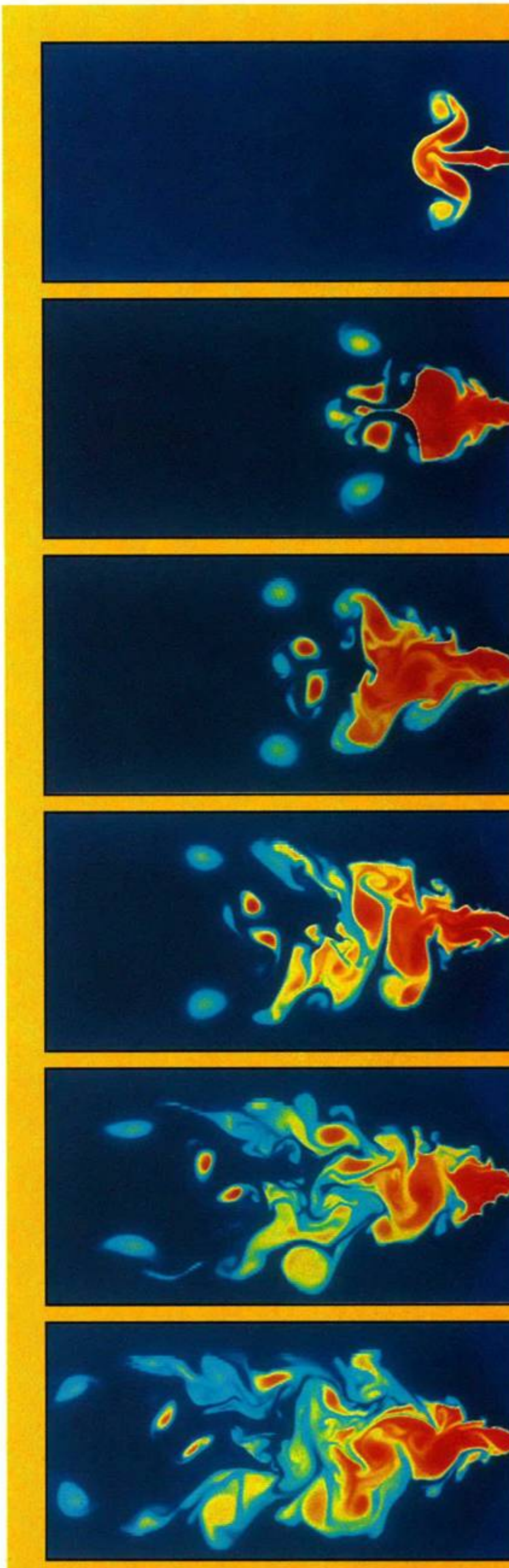
Astronomers have known for more than thirty years that the luminosities of compact cores of radio sources vary in time. More recently, Very Long Baseline Interferometry (VLBI) has demonstrated that new jet knots often appear after a flare in the intensity of an active galaxy or quasar nucleus has been observed. Apparently, the plasma output of the engines in such sources is not constant in time. There is further evidence of variable outputs from galaxies in sources such as 3C 219 where partial jets are observed.

Nearly all previous models of classical doubles assumed that jets were continuously turned on. The variability of the galaxy or quasar core may have important consequences for jet and lobe structures, however. As another example of the insight that can be gained from numerical simulations, David Clarke and I recently ran a series of supercomputer models in which we "turn on" a jet, turn it off for an equal period of time, then turn it on again. The results show that a "reborn" jet propagates much more quickly (down the evacuated channel left by the previous jet) than does the original jet. Such reborn jets catch up quickly with the previous working surface, and this could explain why measured velocities of some newly-seen knots in VLBI images of jets are moving at different, sometimes greater, velocities. We also found that when the simulated jet is turned off, the lobe and hot spot expand and cool. This agrees with observations in which an active jet in a classical double is seen on the side with the more compact lobe hot spot.

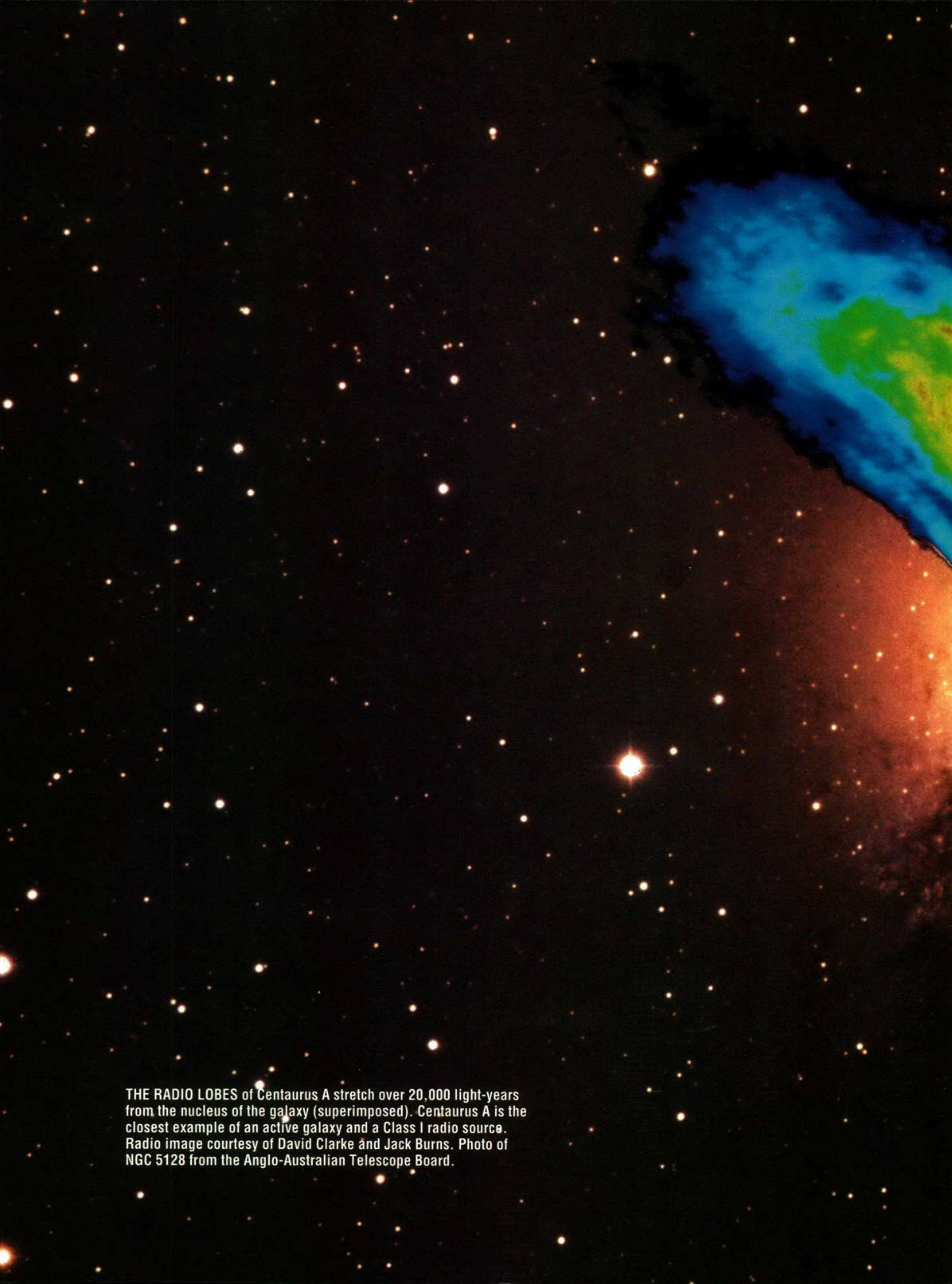
Most importantly, the time-variability problem illustrates the control and flexibility that astronomers now have in studying jets. Because of the long lifetime of radio sources (hundreds of millions of years), we see only a brief moment in the total life of a jet with our radio telescopes. It is difficult, then, to understand the long evolutionary history of such sources. With a supercomputer, however, we can collapse this timeline, watch how sources evolve under different circumstances, and attempt to understand the history behind the variety of sources that we observe with the VLA. Supercomputers allow us to control both time and space.

Disruption of Radio Jets

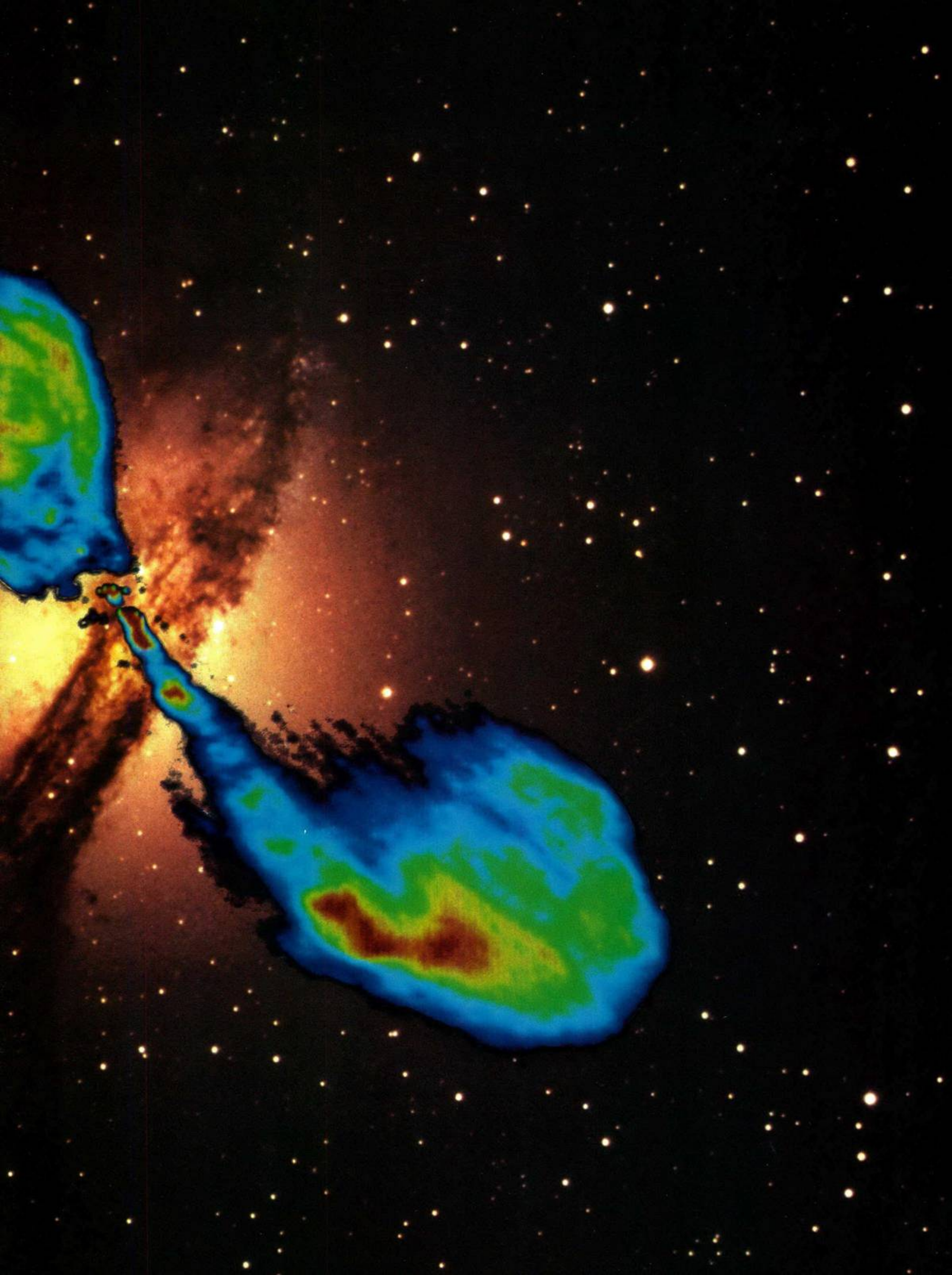
Now that some progress has been made toward understanding the jets in classical doubles, we have begun to turn our attention toward understanding the more complex jet structures associated with Class I sources. There is a subset of radio galaxies, termed wide-angle tailed sources, that lie at the break between Class I and Class II. Aileen O'Donoghue of St. Lawrence University has recently produced some exquisite VLA maps of these sources identified with optically bright galaxies at

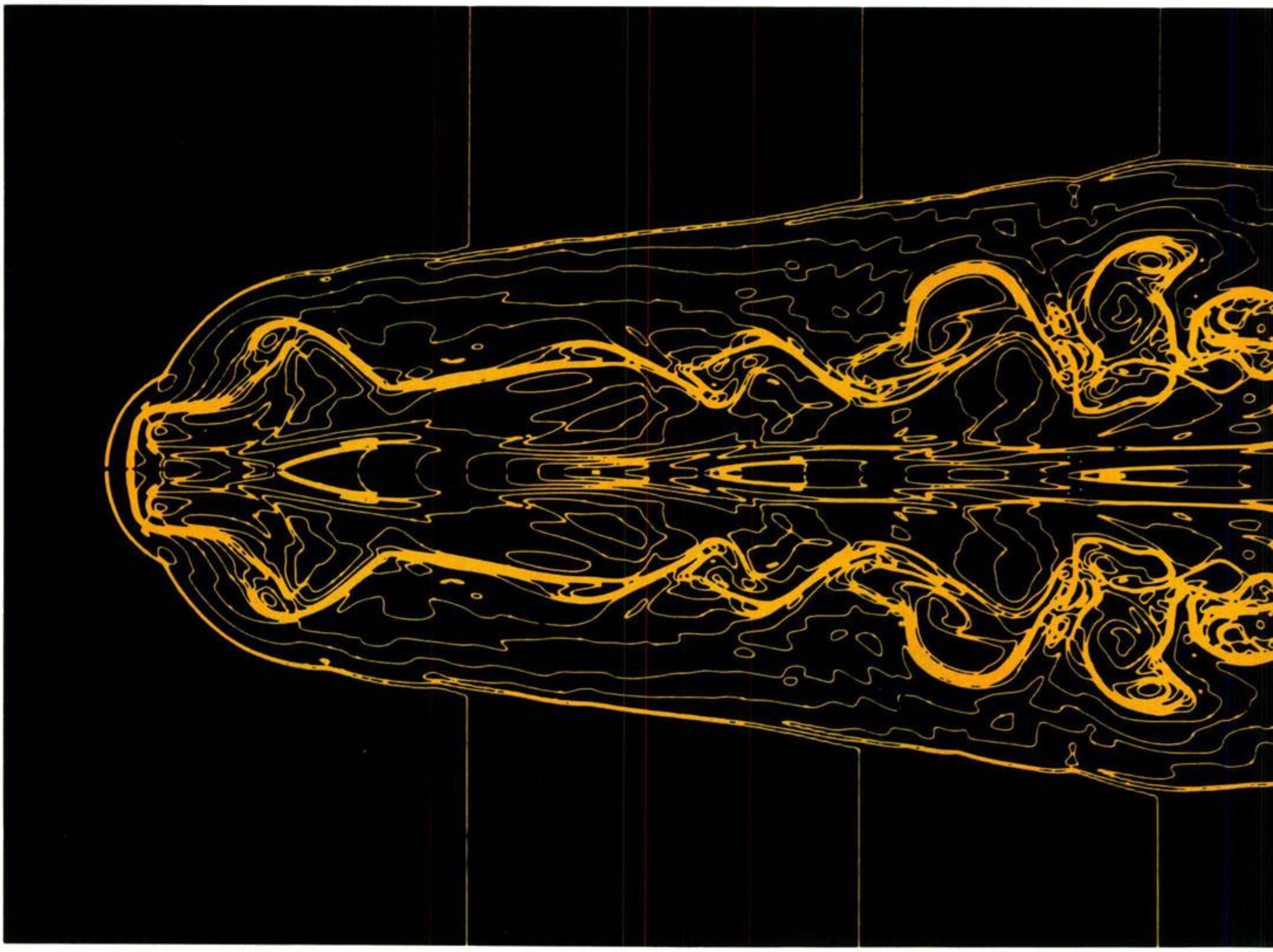


A JET DISRUPTS when it encounters the dense intergalactic medium, according to this computer simulation. The jet inlet is on the right and propagates to the left. Areas of greatest density are colored blue; least dense areas are red. Courtesy of Jack Burns.



THE RADIO LOBES of Centaurus A stretch over 20,000 light-years from the nucleus of the galaxy (superimposed). Centaurus A is the closest example of an active galaxy and a Class I radio source. Radio image courtesy of David Clarke and Jack Burns. Photo of NGC 5128 from the Anglo-Australian Telescope Board.

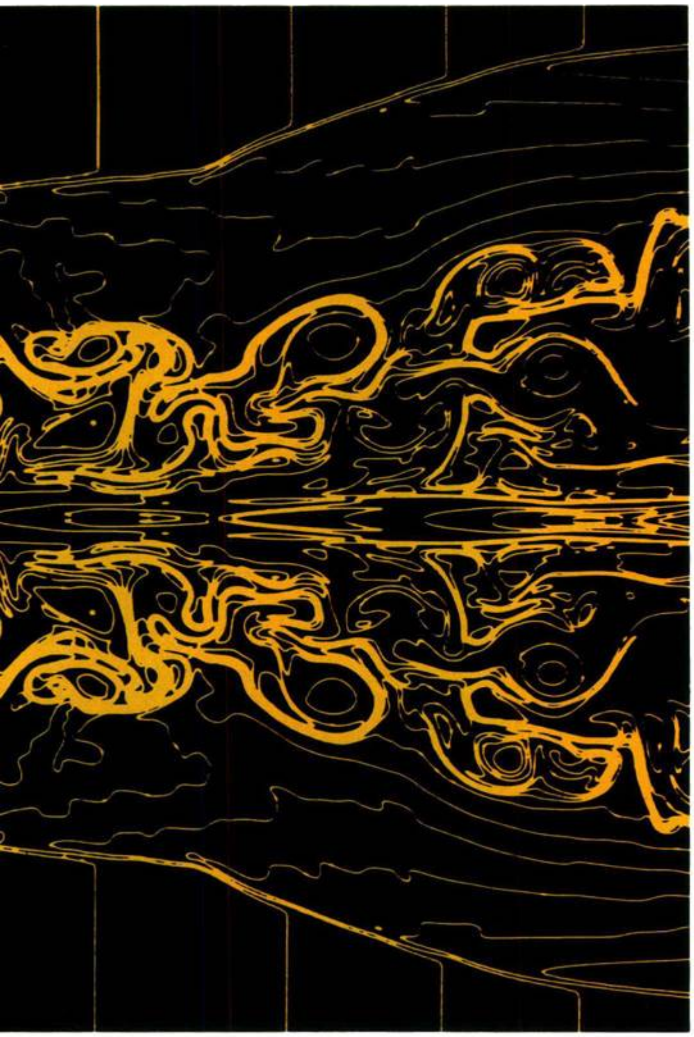




SUPERSONIC JETS, like those emerging from 3C 219 (left) and M87 (above right), consist of complex structures. Pushed out ahead of the jet's working surface is the bow shock. Behind the bow shock is the "contact discontinuity," a boundary that separates the shocked intergalactic material from a cocoon of plasma, which is blown back down the outer edge of the jet by the intergalactic wind. Material in the cocoon is subsonic and highly turbulent. The eddies exert a force back upon the jet that produces crisscross shocks, which may in turn produce bright, compact knots, like those in M87. Schematic courtesy of Jack Burns. Photo of 3C 219 courtesy of David Clarke. Photo of M87 courtesy of NRAO/AUI.

the centers of clusters. Wide-angle tailed sources have twin jets that are very straight. They travel outward some 30,000 to 100,000 light-years from the galaxy's nucleus, which is still within the galactic halo, where they suddenly disrupt, flare, and bend. The origin of this sudden disruption is a mystery.

Michael Norman, postdoctoral fellow Martin Sulkanen, and I think that a "pressure wall" may exist at the interface between the interstellar medium of the galaxy and the intergalactic medium. Such a pressure wall may be produced by a supersonic "wind" that blows radially outward from the core of the active galaxy. When the wind strikes the stagnant intergalactic gas, a shock is produced. We theorize that if a mildly supersonic jet



passes through such a shock, the jet won't be able to readjust to the sudden change in external pressure and will disrupt.

Our numerical simulations have verified this theory. When the jet strikes the external shock, an internal Mach disk, or a planar shock, is formed in the jet. This causes the jet material to decelerate and become subsonic. The laws of fluid dynamics tell us that the subsonic jet must expand if its pressure is to balance with the pressure of the surrounding medium. Thus, the jet is seen to flare abruptly as in the VLA observations. Furthermore, because of its lower velocity, a subsonic plasma is highly susceptible to turbulence. Thus, the expanded jet or tail is very chaotic, much like smoke rising from a chimney.

Since our simulations reproduce the basic observations so well, we think there may be a previously unrecognized gaseous component in elliptical galaxies. These galaxy pressure walls are recognized as a result of new VLA radio observations coupled with supercomputer simulations.

The research doesn't stop there, however. Jun-Hui Zhao, a graduate student at the University of New Mexico, has recently demonstrated that an external shock is not the only mechanism that will disrupt a jet. X-ray observations of galaxy clusters with dominant central galaxies often show evidence that gas in the cluster is cooling and falling in toward the center of the cluster. The gas cools by radiating x-rays and is driven toward the cluster's center by pressure from the hotter gas in the outskirts of the cluster. The particular profile of intergalactic gas pressure in these "transonic" cooling flows — the pressure drops toward the center of the cluster as the flow becomes supersonic — also appears to disrupt jets according to our numerical simulations. Again, this agrees with observations in which clusters with cooling flows have jets that are small in length with apparent disruptions near the cluster center.

The work to date has shown that numerical simulations can be a powerful tool for understanding extragalactic radio sources. However, these previous numerical simulations have been constrained to two dimensions due to limited memory in the supercomputers. With the arrival at the University of Illinois of the Cray 2 computer, which has more memory capacity than previous supercomputers, we are now expanding our simulations into three dimensions. This will allow us to tackle a broader range of problems, such as the bending of radio jets in head-tail sources.

We have entered a new era in astronomy in which computers have given us the power needed to image radio emissions from galaxies and quasars with unprecedented clarity. At the same time, supercomputers have permitted us to study the evolutionary history and underlying physics of extragalactic radio sources with numerical simulations. In the exciting years to come, powerful groundbased radio telescopes, the *Hubble Space Telescope*, and computers will allow astronomers to view and model the cosmos with a bold new perspective, yielding fresh insights into the structure and origin of cosmic jets. ☐

Jack O. Burns is head of the astronomy department and professor of astronomy at New Mexico State University. He is also an adjunct researcher at the National Radio Astronomy Observatory and has been a long-term visiting scientist at the University of Illinois' National Center for Supercomputing Applications.

Raising Hubble

With the *Hubble Space Telescope* safely delivered to orbit, the observatory's extended family gets down to the difficult task of rearing its prodigy.

by Stephen Cole

On the afternoon of Wednesday, April 25, the *Hubble Space Telescope* came into the world. *Hubble* had survived the rigors of launch inside the space shuttle *Discovery* the day before and had opened its two solar arrays and high-gain antennas that morning. With self-generated electrical power coursing through its systems, *Hubble* was ready to go it alone. At 3:38 p.m. the shuttle's remote manipulator arm released the telescope and *Hubble* was away.

After release, project scientist Al Boggess walked pensively among the *Hubble* exhibits in the Goddard Space Flight Center's visitors' area, which was serving as the news room during the mission. "I feel a lot happier now," Boggess said. "I'm looking forward to finally getting our hands on it."

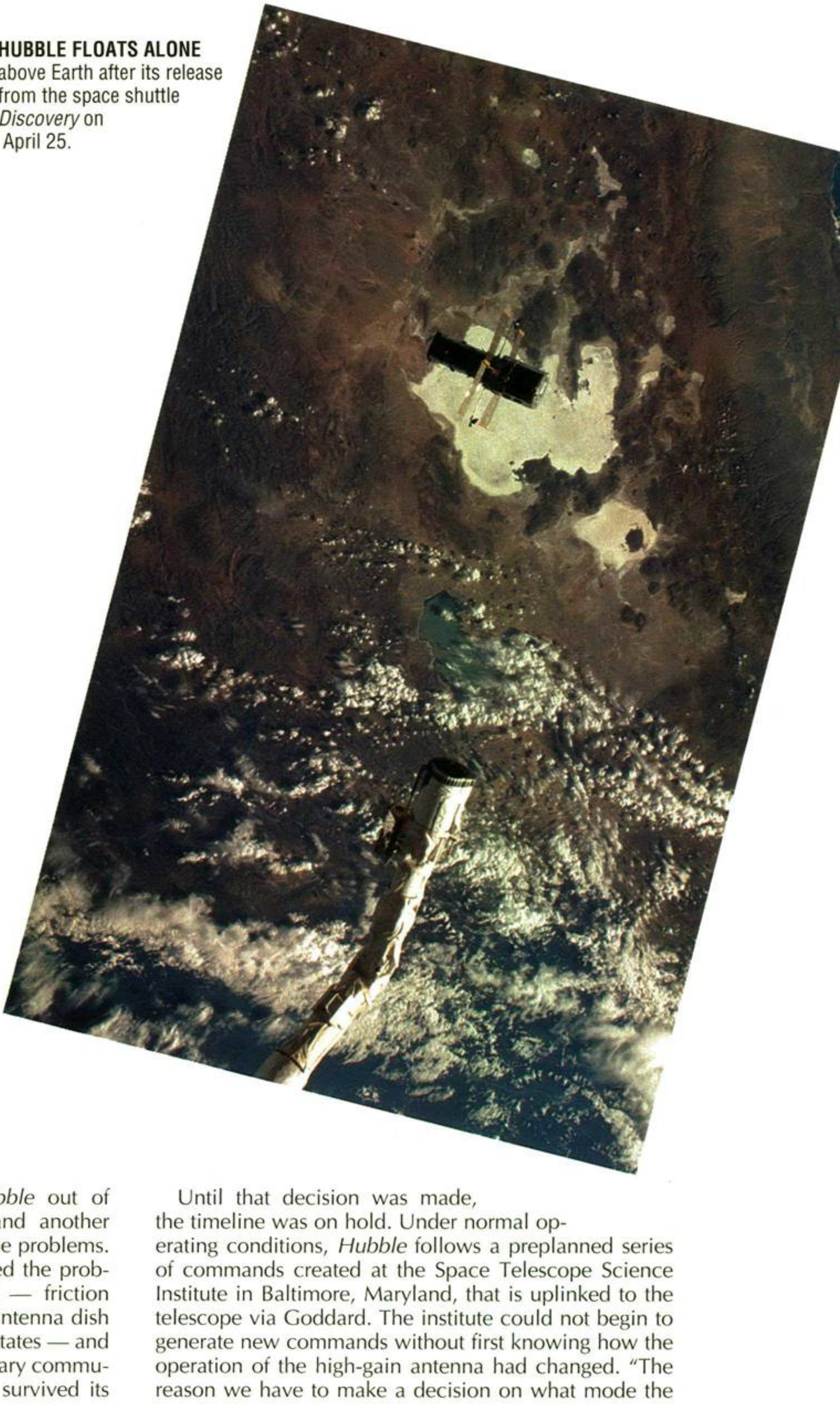
Hubble was now out of the hands of shuttle astronauts and under the control of engineers and mission managers in Greenbelt, Maryland, in the space telescope control room of Goddard's Building 3. Working around the clock, these people would spend the next three months getting the newborn observatory on its feet, making sure that all its systems — communication, pointing, optics, science instruments — were in good working order. Once this initial check-out, called orbital verification, is completed and *Hubble* is pronounced fit, the teams of astronomers who built the science instruments will run their equipment through its paces and begin performing observations. At that point, which should be late this summer, *Hubble* will begin to show off its prodigious talents.

The progress of this coming of age was laid out in a minute-by-minute timeline by mission planners. Within one week of release from the shuttle, *Hubble* would open the door covering the front of the scope, establish communication with Goddard through its high-gain antennas, refine its ability to point steadily in a given direction, and begin the process of focusing its optics. At the end of its first week in orbit, on Tuesday, May 1, *Hubble* would take its "first light" image through its Wide Field/Planetary Camera, giving the world its first view of the universe through the partially trained eye of the new observatory.

But, as is usually the case when raising a newborn, bringing up *Hubble* did not go strictly by the book. Early on the morning of Friday, April 27, as *Hubble* was performing its first large-scale movements in space — maneuvers designed to test the scope's ability to control its position before the door covering its optics was opened later that morning — *Hubble's* software-based safing system detected a problem with the motion of one of the high-gain antennas. The system responded by placing the telescope in inertial hold mode, which maintains the spacecraft's present orientation in space. Communication with the ground switched to *Hubble's* low-gain antennas.

Since this type of hold was not a particularly serious problem, mission controllers at Goddard proceeded with the opening of the aperture door at 9:45 a.m. The door opened without a hitch, but the vibrations produced by the door hitting the mechanical stop unexpectedly sent *Hubble* into a more serious hold mode called software Sun point. This mode takes the spacecraft out of whatever position it's in and fixes it with the solar arrays facing the Sun, for maximum power generation, and the open aperture pointing 90 degrees away from the Sun.

The timeline lost one day as mission controllers



HUBBLE FLOATS ALONE above Earth after its release from the space shuttle *Discovery* on April 25.

GROUND CONTROLLERS TALK to *Hubble* from the space telescope control center at Goddard Space Flight Center in Maryland. NASA photos.

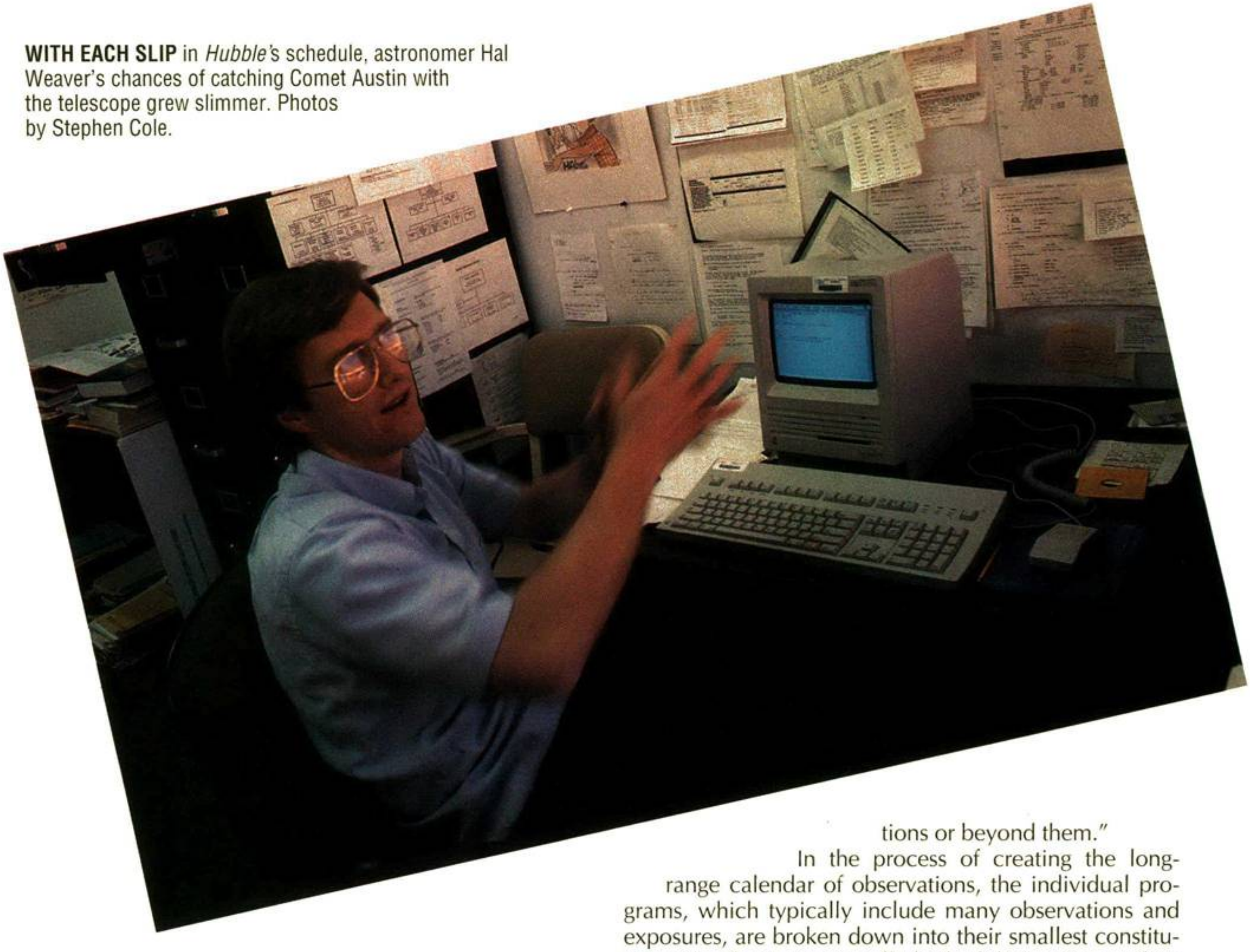
worked to get *Hubble* out of these hold modes and another day as they investigated what had caused the problems. By Sunday night, April 29, they had isolated the problem with High-Gain Antenna Number 2 — friction caused by counterweights attached to the antenna dish rubbing against a power cable as the dish rotates — and returned it to operation. *Hubble* had its primary communications hardware back on line and had survived its first major challenge.

Mission controllers were able to fix the high-gain antenna problem by limiting the movement of the antenna dish. The dish, instead of being able to rotate 100 degrees in either direction as it tracked the satellite that relays its data to Earth and sends along commands from the ground, would be restricted to about 60 degrees so it would not rub against the offending cable.

Until that decision was made, the timeline was on hold. Under normal operating conditions, *Hubble* follows a preplanned series of commands created at the Space Telescope Science Institute in Baltimore, Maryland, that is uplinked to the telescope via Goddard. The institute could not begin to generate new commands without first knowing how the operation of the high-gain antenna had changed. "The reason we have to make a decision on what mode the high-gain antennas will operate in before we proceed with orbital verification," explained Jean Olivier, chief engineer for orbital verification at the Goddard control room, "is that if we don't, we would be forcing the institute to gear up to operate in one way and then later come back and change their mode of operation. We'd prefer not to jerk them around that way."

When the restricted "movement envelope" for the an-

WITH EACH SLIP in *Hubble's* schedule, astronomer Hal Weaver's chances of catching Comet Austin with the telescope grew slimmer. Photos by Stephen Cole.



tennas was established on Monday, April 30, the institute immediately began to build another command load that would return *Hubble* to normal operation on Tuesday at 11 p.m. Command loads are designed to begin at a specific time and automatically execute commands for a certain number of hours or days lasting as long as a week.

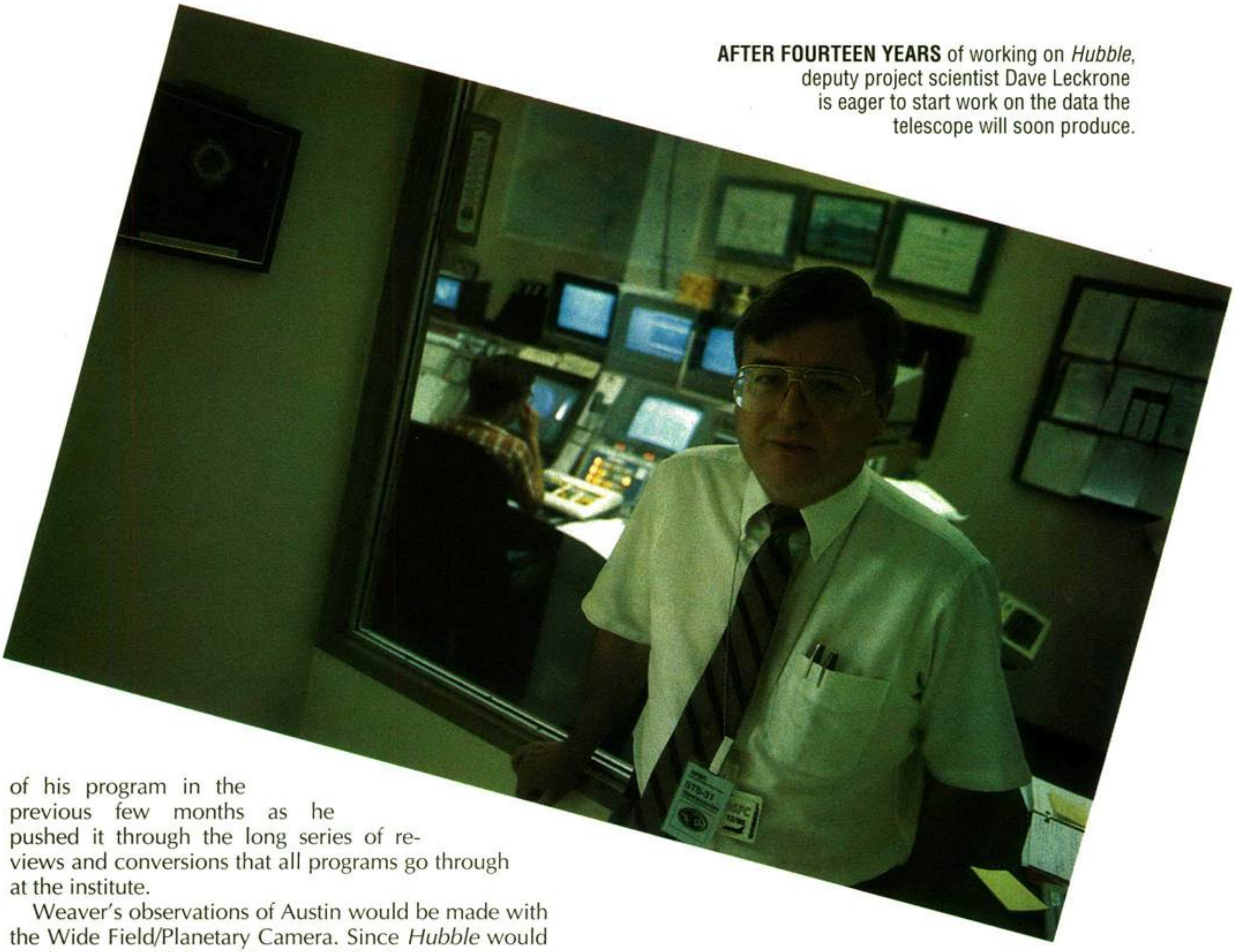
Once *Hubble* is a fully functional observatory, these command loads will contain all the instructions that tell *Hubble* to point at a certain object, turn on a certain instrument, and take an exposure for a certain length of time. At the end of April the institute reviewed the first draft of the long-range schedule for the first series of observations to be made by the telescope. This initial observing period is devoted exclusively to the programs developed by the *Hubble* instrument team members and project staff — the guaranteed-time observers.

"These programs are very well-tuned, very mature," said Bruce Gillespie, head of the institute's user support branch. "We've been through six or seven iterations of these programs with the observers over the past five years. We are very confident that the programs in our database will produce science data as well as anyone can predict without knowing how well the instruments will work. The only big surprise will be whether the instruments and the telescope perform up to our expectations or beyond them."

In the process of creating the long-range calendar of observations, the individual programs, which typically include many observations and exposures, are broken down into their smallest constituent parts. These pieces, called scheduling units, are then arranged into a master calendar that maximizes *Hubble's* observing time by clustering together similar observations from different programs. "This stage is a whole new hoop to jump through," said Gillespie. "We've had to go back to about 20 percent of the observers and revise their programs a little to fit better into the schedule."

Although no observing programs are planned in the initial three-month check-out, during *Hubble's* first week Hal Weaver, a staff astronomer at the institute, was hoping that the schedule builders would find a tiny opening in the timeline around May 25 to fit in a quick look at a unique target of opportunity — Comet Austin. Last December, when Austin was predicted to become a 2nd-magnitude comet as it passed Earth in May, Weaver started lobbying for a chance to use *Hubble* to observe this unusually bright comet. NASA headquarters also inquired about what useful observations *Hubble* could make of Austin. In January the space telescope science working group, headed by Al Boggess, approved a resolution backing the idea of squeezing an Austin observation into the early orbital verification period.

"This is a completely renegade program," said Weaver as he transferred his observing program files from one institute computer to another with his desktop MacIntosh. Weaver had been through several revisions



AFTER FOURTEEN YEARS of working on *Hubble*, deputy project scientist Dave Leckrone is eager to start work on the data the telescope will soon produce.

of his program in the previous few months as he pushed it through the long series of reviews and conversions that all programs go through at the institute.

Weaver's observations of Austin would be made with the Wide Field/Planetary Camera. Since *Hubble* would not be up to its full tracking capability by May, Weaver planned an exposure of less than half a second to avoid smearing the image. Even with such a brief exposure, *Hubble's* exceptional spatial resolution has the potential of homing in on activity around the nucleus and revealing the darkness and size of the nucleus, Weaver said.

By the end of April, it was clear that Austin was not going to be the "monster comet" it had promised to be. "But even if Austin is only as good as Halley," Weaver said, "that's still a fantastic target." The prospect of getting an Austin observation into the schedule was uncertain as *Hubble* entered its second week in orbit. "Right now I don't even know what to call the odds as to whether or not we'll get this done," said Weaver. "Every problem that surfaces makes it less likely."

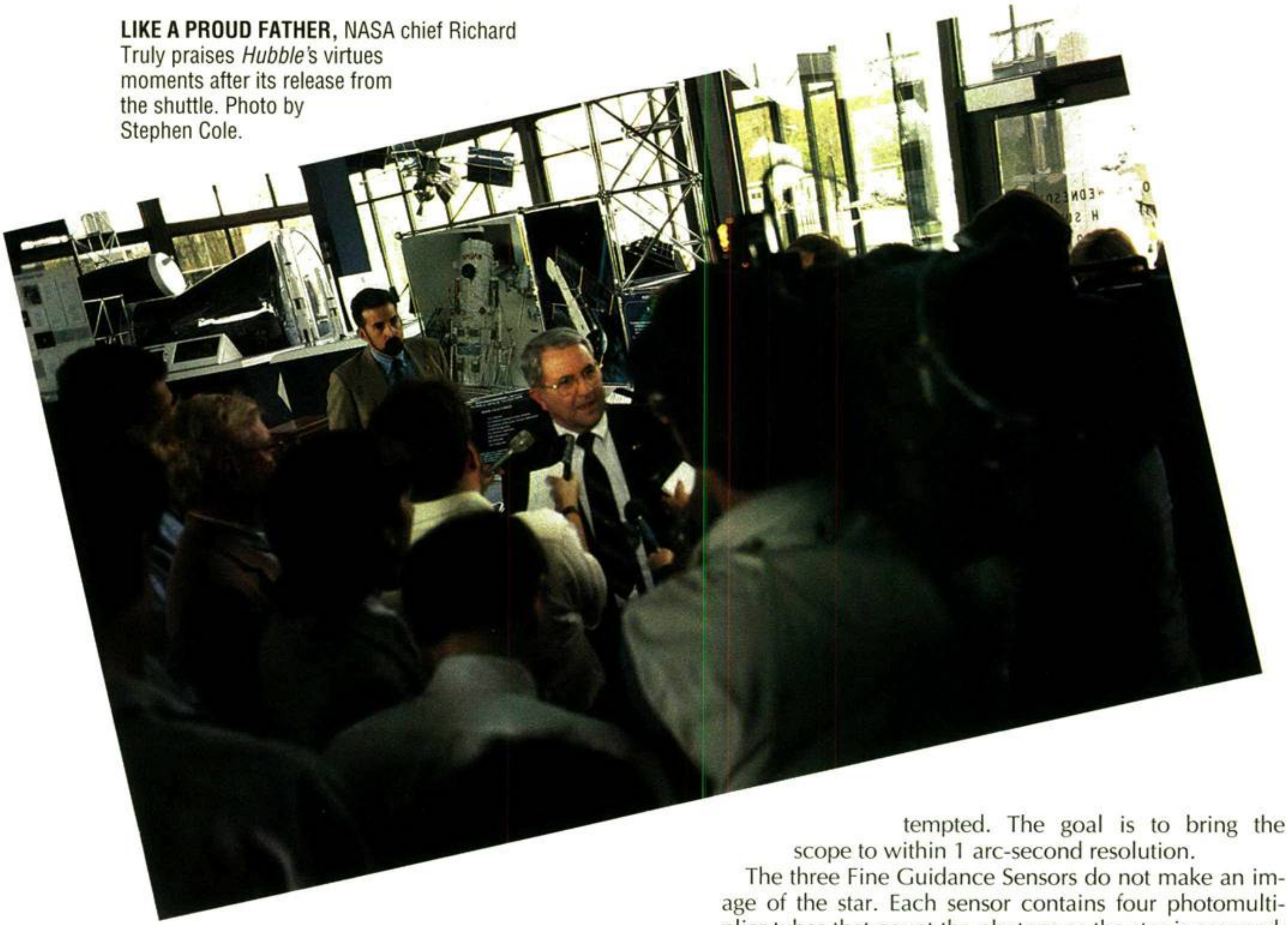
And, unfortunately, another problem arose just as the institute was preparing a new command load to return *Hubble* to the timeline. On the evening of Monday, April 30, while the telescope was being controlled by "health and safety" command loads created at Goddard — instructions that keep the spacecraft systems on standby — an irregularity was detected in *Hubble's* pointing system. The investigation of the pointing problem would last for a week, another major delay.

Hubble's pointing control system uses a variety of techniques to achieve precise, reliable pointing of the telescope. Its ultimate goal is to provide observers with pinpoint accuracy in locating targets and rock-steady tracking of those targets for long periods of time. When *Hubble* first controlled its own movements after being released by the shuttle, its orientation in space was determined using sightings of the Sun through four Sun sensors. Pointing was accurate to only 4 or 5 degrees with these sensors. When the three fixed-head star trackers added their input later, pointing accuracy was improved to 1 or 2 degrees. "These are the first baby steps along the way to one-hundredth of an arcsecond pointing accuracy," said Steve Terry, director of the orbital verification graveyard shift.

But when the three Fine Guidance Sensors, the instruments that bring *Hubble* to a fraction of an arcsecond accuracy, came on line and performed a pattern match test (in which the star field they see is compared with star charts in computer memory to evaluate how well the whole pointing system is working), a slight cyclical motion was detected that prevented the sensors from keeping a firm lock on stars. Mission controllers, after a week of running diagnostic tests and analyzing data sent down from the telescope through Monday, May 7, eventually mitigated the oscillation problem.

During that week, *Hubble's* science instruments were powered up, one by one, to their low-voltage level. The temperature of the instruments was being monitored, as was the atmospheric pressure inside the instrument compartment at the rear of the telescope. Mission con-

LIKE A PROUD FATHER, NASA chief Richard Truly praises *Hubble*'s virtues moments after its release from the shuttle. Photo by Stephen Cole.



trollers wanted to make sure the gas pressure inside the compartment, produced by water slowly outgassing from the spacecraft structure and by residual atmospheric air, reached a sufficiently low level beforethey switched on the high-voltage instruments. Too high an atmospheric pressure in the compartment could cause arcing when tens of thousands of volts were sent into the instruments.

Although the science instruments successfully completed milestone after milestone in their activation, the overall timeline was falling increasingly behind schedule. As a result, Hal Weaver received a call from the project office at Goddard informing him that a Comet Austin observation was no longer possible. The delays had squeezed out any spare time that might have been available and, as yet, the telescope had not even been focused. "Sometimes comets disappoint us like this," said Weaver, commenting on both the loss of his *Hubble* observation and the fading prospects of the comet itself.

On Tuesday, May 8, with the pointing problem lessened, the *Hubble* timeline moved into its next major activity: bringing the telescope's mirrors into focus. The initial step in the process, called Bootstrap Phase A, uses the Fine Guidance Sensors to look at stars and determine how far out of focus they are. Commands are then sent to move *Hubble's* secondary mirror a small amount. The stars' images are again observed to see if the image has become smaller. During the day-and-a-half-long operation, a dozen star measurements are attempted. The goal is to bring the scope to within 1 arc-second resolution.

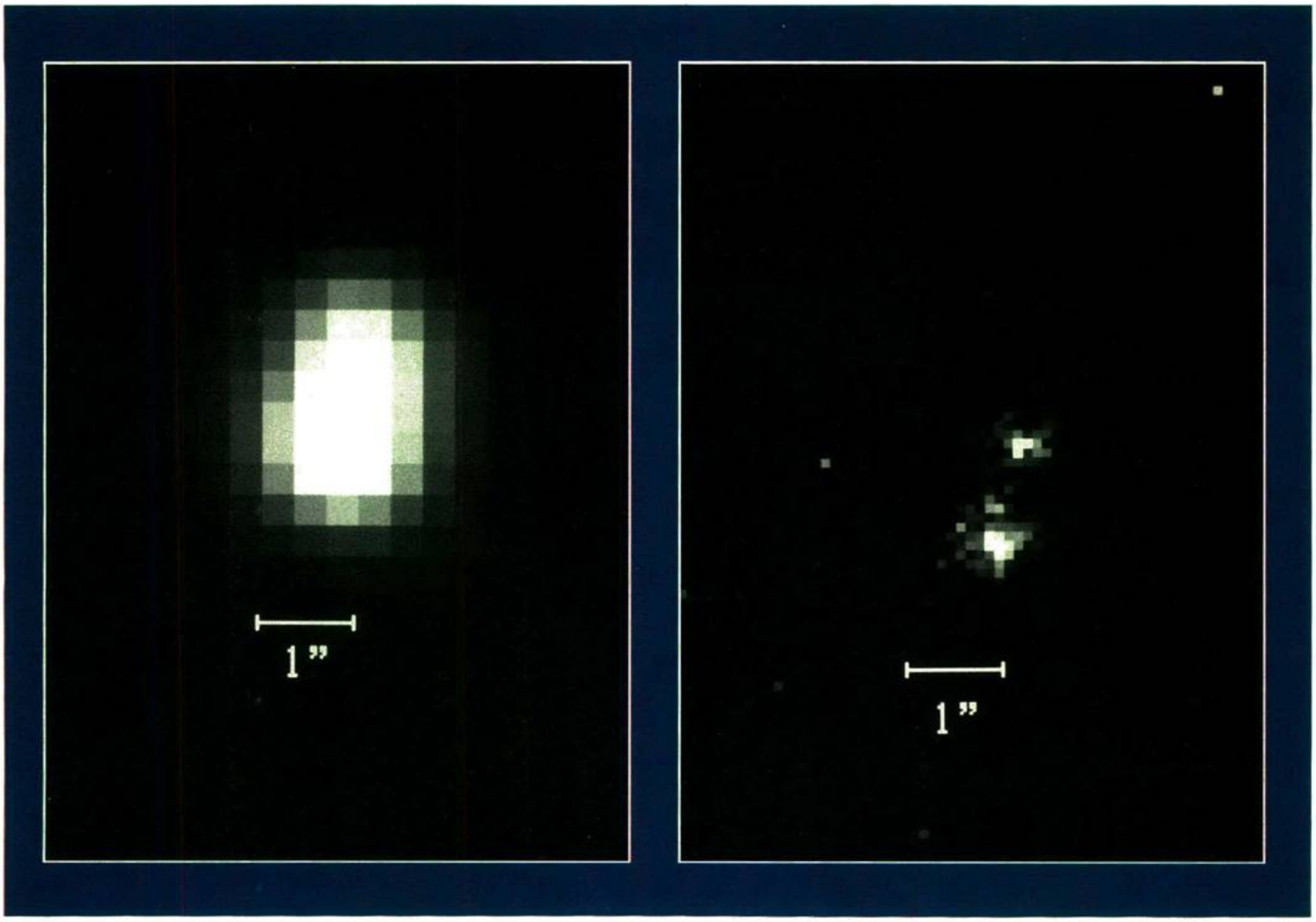
The three Fine Guidance Sensors do not make an image of the star. Each sensor contains four photomultiplier tubes that count the photons as the star is scanned; the photon count is then plotted as a light curve. The shape of that curve tells how well the image is focused. A curve with a broad hump is out of focus; a curve with a sharp peak is in better focus. Once the focus has been improved to the 1-arcsecond level, the "first light" image is taken to verify the quality of the focus. After that another, much more precise round of focusing begins.

The first Bootstrap Phase A, however, was not able to focus *Hubble* because the telescope was pointing in the wrong direction. A human computational error in the coordinates for NGC 3532, the open star cluster that had been selected to be *Hubble's* first target, caused the scope to be pointed half a degree away from the cluster in a sparse region of sky.

"This caused quite a lot of anguish for about twenty-four hours," said Dave Leckrone, *Hubble's* deputy project scientist at Goddard. "Project managers surely have more gray hair than they had before."

Another try was made on the weekend of Saturday, May 12, but the Fine Guidance Sensors were again unable to lock onto stars, this time because of an unsteadiness in the spacecraft's position. A third attempt on Tuesday, May 15, was a success. Nine stars were observed and nine light curves produced. The secondary mirror was moved for the first time, and the focus improved slightly. Bootstrap Phase A was repeated two days later to home in on the resolution target.

At 11:12 a.m. on Sunday, May 20, *Hubble's* Wide Field/Planetary Camera took its first image, a 1-second exposure that showed a handful of fuzzy stars in the cluster. A second half-minute exposure followed, which



HUBBLE'S FIRST VIEW through its Wide Field/Planetary Camera was of a handful of stars in NGC 3532. A double star in that image (right) shows up clearly as two stars after computer processing; in a high-quality, ground-based image (left) the two components blur together. NASA photo.

verified that *Hubble's* pointing was steady enough to minimize smearing of the stellar images. The resolution was slightly better than what ground-based telescopes can achieve on a good night.

Although this image was nothing spectacular, Dave Leckrone knew how much more *Hubble's* instruments would be able to see once the telescope attained its full capabilities. Leckrone, who has held several key roles in the *Hubble* project since 1976, plans to analyze the composition of stars when his guaranteed-time-observer programs come up in the observing schedule. With *Hubble's* resolving power and sensitivity to ultraviolet wavelengths, Leckrone intends to catalog the elements in stellar atmospheres and, thereby, to trace the evolutionary history of chemical elements in exquisite detail.

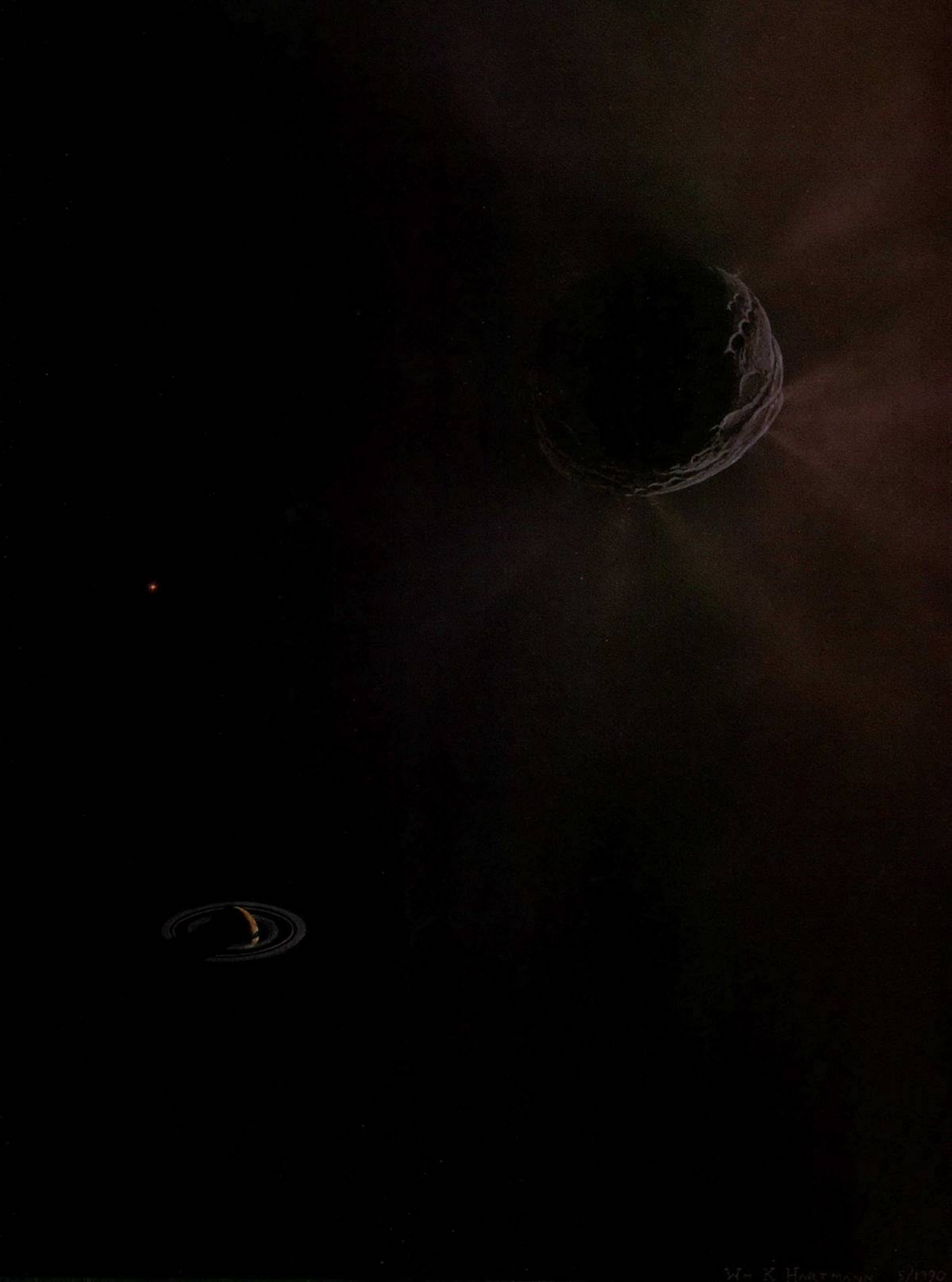
"Probing the composition of stars by looking at their visible-light spectra from ground-based telescopes is an old subject that has gone about as far as it can go," said Leckrone. "To make big gains in this field we hav to go to the ultraviolet where many very important spectral lines occur. This is largely unexplored territory right now. Even data from the *International Ultraviolet Explorer* is of marginal quality for this type of work. But the spectra we'll get with the Goddard High-Resolution Spectrograph on *Hubble* will be so detailed that I could easily spend several lifetimes analyzing it."

One of Leckrone's observing programs will inventory the elements of two very different stars, Sirius and a chemically peculiar star named Chi Lupi. "We will produce the first extremely-high-resolution ultraviolet atlases of stars. These atlases will be very time-consuming. I hope we end up with enough observing time to do them."

With the elemental data, Leckrone and other stellar astronomers will be able to trace the history of stars and galaxies as well. "The elements are tracers of stellar evolution, driven by the nuclear processing of matter in the stars. Elemental abundances can give us some idea of how the process of chemical evolution has gone on through the whole life of the Galaxy. We can even use them as probes below the visible layers of stars to gain an understanding of the physical processes that are going on there."

But before Leckrone can turn from his concerns with bringing *Hubble* to maturity and begin to use some of the data it will produce, several more months of hard work lie ahead for all the project staff and instrument teams. A more precise focus of the telescope's optics must be attained. All the science instruments have to be fully powered up, tested, and calibrated before they can send science data to the ground. The hope is that before Thanksgiving, *Hubble* will be out of its infancy and well on its way to adulthood.

"Like many other people on this project, I've dedicated most of my professional life helping to make the *Hubble Space Telescope* a reality," reflects Leckrone. "With the end of the verification period, I hope I'll be able to get back to doing science. It's extremely exciting, and I'm eager to get on with it." □



W. K. HARTMANN 5/1990

The Changing Face of Chiron

Once an asteroid, now a comet, Chiron is changing astronomers' understanding of these small solar system bodies.

by William K. Hartmann

In the nineteenth century, two classes of interplanetary bodies seemed clear: asteroids and comets. In a telescope, asteroids looked like stars; comets looked fuzzy and showed emission lines in their spectra from various gases. Further study showed that asteroids were rocky, but comets had abundant ices that turned from solid to gas by sublimation when warmed by sunlight. The gas expanded into space and carried off trapped dust particles, creating a coma and tail of dust and gas.

Some thirty or forty years ago, astronomers began to notice similarities between the orbits of some comets and asteroids. They began to wonder if some asteroids were actually "burnt-out" comets that had been depleted of ice. Nonetheless, so strong was the nineteenth-century division between asteroids and comets that even in the 1950s asteroid and comet scientists spoke a different scientific language and attended different meetings. Asteroid specialists gravitated toward studies of mineralogy and impact phenomena; comet scientists were spectroscopists. This division of research forestalled a more detailed understanding of the relationships among small bodies in the solar system.

Things began to change several years ago, however. In 1988 University of Hawaii observer David Tholen, NASA researcher Dale Cruikshank, and I observed that the unusual asteroid named Chiron had suddenly brightened, apparently transforming itself from an asteroid to a comet. We had found evidence that a so-called asteroid was acting like a comet, proving that the traditional distinction is an oversimplified way to think of small objects in the solar system.

Before 1988, Chiron had already attracted notice because it was the most remote asteroid discovered. Eleven years earlier, Lowell Observatory astronomer Charles Kowal discovered and cataloged a faint asteroid and named it 2060 Chiron. Kowal estimated from its brightness that Chiron was between 60 and 200 miles in diameter and orbited the Sun at a mean distance of 13.7 astronomical units (AU), or about 1.3 billion miles. Kowal soon found that Chiron has an elliptical path that carries it between 8.5 AU, just inside Saturn's orbit, and 18.8 AU, just inside Uranus' orbit. The most distant asteroids previously known orbited at distances of about 5 to 6 AU, in the general vicinity of Jupiter. Chiron takes 50.7 years to move around the Sun and is now heading inward toward its perihelion passage in 1996.

From the moment of its discovery, scientists were perplexed by this distant asteroid. Their first goal was to determine something about its composition. In 1981 Dale Cruikshank, Dutch researcher Johan Degewij, University of Hawaii astronomer Richard Capps, and I made observations of Chiron and other remote asteroids with NASA's infrared telescope at Mauna Kea Observatory in Hawaii. We found that Chiron exhibited the same infrared colors as other dark, remote asteroids. This finding was significant because it tied Chiron in to some patterns of relationships among asteroids. At about the same time, observers Edward Tedesco and John Gradieestablished that the asteroid belt is strikingly arranged in zones of different composition, which changes with increasing distance from the Sun.

More importantly, a dramatic transition exists at about 2.7 AU from the Sun, right in the middle of the asteroid belt. Inside that zone, most asteroids are light-colored, reflecting about 8 to 30 percent of the sunlight that strikes them. There is a narrow transition region around 2.7 AU, and beyond this region asteroids are very dark, reflecting only 2 to 8 percent of the light.

What causes this difference in reflectivity, and why are distant asteroids as dark as black velvet? Astronomers think the dark color comes from the presence of black, powdery carbon compounds that condensed only in the outer, colder part of the solar system. Furthermore, University of Hawaii observer Roger Clark has shown that even if a body has a large amount of light, transparent minerals such as ice, black will dominate its overall color because light passes through the light material and reflects off the dark.

This led to a prediction about Chiron's surface composition. Our research group measured Chiron's color and found it to be like that of other dark, presumably carbon-rich asteroids. We knew that only these dark asteroids are found in the outer solar system. We also knew that even a little of the black carbonaceous powder could go a long way in darkening an object. Thus, our educated guess was that Chiron's surface is dark and involves at least some of the carbonaceous material characteristic of other remote asteroids.

The striking transition from light to dark objects in the mid-asteroid belt is significant. It is the key distinction between types of solar system bodies, rather than the supposedly distinct difference between asteroids and comets.

To fully understand the solar system's distribution of light and dark objects, we decided to investigate the various types of dark asteroids in more detail. They are divided into three classes according to color. C class asteroids are found in the outer asteroid belt and are neutral black. P and D class asteroids are successively redder and are located farther out from the Sun, principally in the region of Jupiter. (This redder-than-black color really amounts to brownish-black.)

Some astronomers, notably Faith Vilas of NASA's Johnson Space Center and her coworker Bradford Smith, believe a transition exists among the dark asteroids. They believe that progressively more distant objects are progressively redder in color. This might be caused by a condensation of brightly colored organic compounds at lower temperatures. According to this view, if Chiron originated where we now see it, it should be quite red, being the most distant asteroid of all.

But our research group's measurements showed Chiron was a C class object and was neutral in color like the asteroids in the outer belt. Here was a puzzle. How could an object seemingly native to the outer asteroid belt end up between Saturn and Uranus? Or was our understanding of asteroids wrong?

Why are distant asteroids as dark as velvet?

Other questions arose. If an object's black carbon-rich material is mixed with appreciable ice, its reflectivity increases. Some of the satellites in the outer solar system seem to be composed of mixtures of the black material and the bright ices, but they have had enough internal geologic activity to melt the ices and erupt watery "lava" that froze into bright icy surfaces. Was Chiron big enough to have fresh ice or frost exposed on its surface? Was its reflectivity really as low as other remote asteroids? Clearly, a measure of the reflectivity of Chiron's surface would help resolve these questions, but Chiron is so distant and faint that its reflectivity is difficult to measure.

The next major advance came in 1984, when astronomers Larry Lebofsky, George Rieke, David Tholen, and Marcia Lebofsky, who were then all located in Arizona, published such a measurement. They were able to detect Chiron at far infrared wavelengths which allow measurement of the reflectivity. They got a crude figure of about 10 percent reflectivity. They also measured a neutral color similar to the one we had measured, although they measured this in the visual part of the spectrum, while we had measured in the infrared. They concluded that the data were "consistent with a composition similar to that of C class asteroids, and the [reflectivity] was probably between 6 and 20 percent." Chiron seemed to have the neutral black dust of black asteroids but a bit brighter surface, suggesting it was mixed with a little bright frost.

So far, so good. But all of us who had looked at Chiron were troubled: If you tried to link the neutral colors the Lebofsky team had observed with those we had observed, there was a mismatch in brightness. Either there was an unprecedented jump between the visual and infrared parts of the spectrum (in which case the C class identification was wrong), one of our sets of data was wrong, or Chiron had brightened unexpectedly between 1981 and 1984. (Chiron is brightening slowly as it approaches its closest point to the Sun in 1996. But we are speaking of "brightening" or "fading" relative to its predictable trend.)

The last possibility was intriguing. Maybe Chiron was elongated in shape and therefore changed apparent brightness as it rotated. Could we have caught it at a different rotational position than Lebofsky's group? This chance was eliminated in 1987 when Lowell Observatory astronomers measured the rotation period of Chiron. They found it rotates in 5.9 hours and changes brightness by only 0.09 magnitude, too low to explain the difference.

Several observing teams began to keep watch over Chiron, checking it occasionally to see if it had any unexplained changes in brightness. On February 20, 1988, Dave Tholen, Dale Cruikshank, and I struck paydirt. Observing with NASA's infrared telescope on Mauna Kea, we found that Chiron was half a magnitude brighter than it was supposed to be. Dave Tholen, who was making rough reductions of the data as we worked, recognized this within half an hour, and we were able to confirm it on two subsequent nights. Lowell Observatory astronomers also confirmed it independently some weeks later.

To understand the earlier stages of the brightening, our research team added University of Hawaii comet observer Karen Meech, who was also keenly interested in Chiron and had some earlier unreduced data. The full data collection, once reduced, showed that Chiron had actually begun to brighten dramatically in mid-1987, though no one recognized it at the time. Chiron's brightness peaked in early 1989, a year and a half after the brightening began. Then it began to fade.

We immediately suspected that the anomalous brightening might be a cometary outburst. However, Chiron was about 13.0 AU from the Sun when the brightening began, and this is awfully far out for a comet to show activity. But it was not unprecedented. Karen Meech and David Jewitt had already set the record distance for comet activity when they observed a coma around Comet Bowell at a distance of 13.6 AU.

Could Chiron, too, behave like a comet at that distance, far beyond Saturn? Most comets are seen only in the inner solar system, when their ices are sublimating into water vapor and other gases. At 13 AU from the Sun, water ice could not heat up enough to sublime, but carbon dioxide and other low-temperature ices could change to gas in the faint warmth of the distant Sun. The real test of whether Chiron had become a comet was to prove whether or not it was surrounded by a coma, or fuzzy cloud, of gas and/or dust.

Our research team looked for a coma around Chiron in 1988 but could not detect one. Nonetheless, our theory that Chiron was having a cometary outburst was supported by the fact that as its brightness doubled, the rotational light curve variation dropped in half, to only about 0.04 magnitude. This is what you would expect with the light curve variation being "diluted" by a constant amount of additional light reflected from an unresolved coma.

Meech and astronomer Michael Belton confirmed the comet theory in April 1989 when they detected a faint coma of dust surrounding Chiron. And by considering Chiron's gravity and temperature, Belton proposed an unusual difference between Chiron's coma and that of comets in the inner solar system. The latter emit gases at high velocities, so the dust is carried away from the nucleus, forming a tail. Also, they are small enough that their escape velocities are low, so the dust is at once swept away into the comet's tail and dispersed.

But Chiron's gas is cold and therefore moves away from Chiron very slowly. Furthermore, Chiron is 10 to 100 times bigger than inner solar system comets and has a high escape velocity. Consequently, dust from a Chiron outburst probably does not escape Chiron's gravitational pull but hangs around as an extended dust cloud, following Chiron as it orbits the Sun. Some of Chiron's larger dust grains may fall back onto its surface, reestablishing a dusty surface, only to blow off again later. This could explain the long timescale of Chiron's brightening and fading. Chiron has faded only slowly since its peak brightness in early 1989, and by early 1990 it remained half a magnitude brighter (once corrected for its changing solar distance) than in its quiescent state of the mid-1980s.

Ceres is a second case of a dead asteroid acting like a comet.

The discovery of Chiron's cometary activity proved once and for all that the concept of pigeonholing small bodies as asteroids and comets was an oversimplification. Instead, questions crucial to the fundamental nature of a body need to be answered. What is it made of? Does it have ice, and if so, what kind? Has it always been far enough from the Sun to prevent its ice from ever subliming? Is the ice actively subliming now, is it too cold to sublime, or is it protected inside the body? And why do some bodies have ice while others don't?

To answer any of these questions, astronomers need to examine the overall environment of the solar system. Generally, the 2.7 AU transition zone in the solar system not only marks the distance at which black carbonaceous compounds began to condense but also lies close to the so-called "frost line," beyond which water ice crystals were part of planets' compositions, and where water of hydration (water molecules trapped in the crystal structure of minerals) began to appear. Most carbonaceous meteorites contain abundant water of hydration, and the dark asteroids have long been suspected of containing water-rich minerals.

Larry Lebofsky emphasized this when he used spectra to discover water of hydration in the minerals of the largest asteroid, Ceres, right in the midst of the belt at 2.8 AU mean distance from the Sun. Lebofsky thought he might have detected frost on Ceres, but this remains unclear. Interestingly enough, Ceres is another black asteroid, generally C-like, with only 6 percent reflectivity, supporting the likelihood that C type asteroids resemble carbonaceous meteorites in composition. All this set the stage for the most exciting news of 1990, when Michael A'Hearn discovered a thin cloud of OH ions around Ceres. Apparently there is enough water ice on or in the minerals of Ceres to produce a thin coma when it is warmed. Here was a second case of a seemingly dead asteroid acting like a comet.

The C class black objects are emerging as one of the most interesting classes of objects in the solar system. They include not only asteroids in the outer belt and some comets but also many small satellites. All the C class satellites appear to have been captured into their orbits around planets, so they probably started as interplanetary asteroids.

I have proposed that these objects were scattered out of the outer reaches of the asteroid belt by Jupiter's gravity during the early days of the solar system. This was a unique period when planets still had proto-atmospheres that might capture errant C class asteroids. And C class asteroids may have contained volatile ices that sublimed and vented from the asteroids, temporarily turning them into comets similar to Chiron and Ceres.

Curiously enough, Mars' black, C class moon Phobos supports these ideas. Its surface has rows of crater pits with raised rims. The straight rows show they are not impacts; the raised rims show they ejected material. Probably they are vents, like those observed on Comet Halley. The rows of pits lie roughly radial to the largest crater, Stickney, and the venting may have occurred along fractures caused by the energetic Stickney impact. Phobos probably acted like a comet during those early days. Data from the *Viking* and Soviet *Phobos 2* missions support this. They revealed that Phobos' density is close to that of black, water-rich carbonaceous meteorites and far below the density of light-colored chondritic stone meteorites. Phobos therefore supports the whole picture of significant relationships among black, volatile-rich "asteroids." Resembling the black, water-rich carbonaceous meteorites, they probably formed with a high water content and have the potential to turn into comets if they undergo sufficient heating.

Thus, the two important classes of planetesimals emerging in the modern picture are the rocky, metal-rich, generally light-colored objects of the inner half of the belt, and darker, carbonaceous objects of the outer solar system, which apparently condensed at cold temperatures and acquired sooty black compounds and perhaps ices. Because of their high water content, they have the potential of developing cometary activity or, in the case of heated satellites, oozing watery material that refreezes to produce bright, icy surfaces over the original dark surfaces.

All this ties in to new discoveries about comets. Conventionally, comets had been described as dirty icebergs, and this brought to mind a white object peppered with specks of dark dirt. A few comet researchers in the 1960s even claimed to have imprecise measurements of high comet reflectivities, said to be 20 to 60 percent or more. Comets were often visualized as being as bright as snow. However, in the early 1980s, when Cruikshank, Tholen, and I began observing remote asteroids and comets, we noticed that all the comets we looked at had the same colors as the remote, blackish asteroids. When we made one of the first detections of Halley during its approach, we got the same result, and we published a paper suggesting it might be black, with a reflectivity like that of the D class asteroids, 4 percent.

This was heresy. Cruikshank was roundly criticized when he presented this result to a scientific meeting prior to the 1986 Halley apparition. In late 1985 Belton summed up the conventional wisdom that Halley's Comet would have a reflectivity around 26 percent.

In other words, even as late as a few months before the *Vega* probes and *Giotto* encountered Halley, the nineteenth-century view still applied: asteroids as a group were darkish, rocky things, and comets as a group were bright, icy things. This turned out to be wrong. *Vega* and *Giotto* measured the reflectivity of Halley's nucleus as 4 percent: a deep black. Several other comet nuclei whose reflectivities have been measured since all turn out to have similar reflectivities of only a few percent.

In our theoretical interpretation, comets, Chiron, and black asteroids probably have porous surface soil layers rich in black, ice-depleted powdery material that may have fallen back and accumulated after previous outbursts. These particles probably became very lightly bonded together, giving this soil a weak tensile strength and a somewhat crusty nature. As the Sun warms this surface and the warmth propagates to the subsurface ices, they begin to sublime. Gas percolates up through the porous dust, building up pressure inside crusty material. Finally, the pressure exceeds the strength of the crusty soil and the crust breaks, discharging gas that carries dust grains off the surface.

Chiron is the biggest well-observed comet nucleus in the solar system.

If sunlight is weak and the sublimation rate is too small to keep up the eruption, the surface discharges its gas supply and the pressure drops back to zero. The comet becomes inactive again. This simple theoretical picture explains why some comets, such as Chiron and Comet Schwassmann-Wachmann 1, combine intermittent outbursts with stages of relative quiescence.

There is still more to Chiron's strange behavior. A reexamination of the photographic plates taken in 1978, soon after Chiron's discovery, showed that Chiron had been anomalously bright at that time, too, settling down to a quiescent behavior in the early 1980s. If those data are right, Chiron had an earlier outburst when it was about 17.5 AU from the Sun — farther than any known comet! This would mean that Chiron has near-surface ices so volatile that they could sublime with only the slightest warming. These might be carbon dioxide or methane ices.

This, in turn, supports an idea that Chiron is a relatively pristine comet, in the sense that it has never spent much time close to the Sun. Otherwise, it would have been much more strongly heated and lost its very volatile ices long ago. It may be a body that has been stored since the early days of the solar system in the great reservoir of comets beyond Pluto — the swarm of comet nuclei known as the Oort cloud after its Dutch discoverer of two generations ago.

The idea of Chiron having an icier surface than most C class objects fits with its reflectivity, which may be a little more reflective than for most C class objects. In early 1990 we obtained a new measurement at Mauna Kea suggesting a reflectivity as high as 12 percent, not far from the old 10 percent value of Lebofsky and his coworkers, but complicated by the presence of the new coma. In any case, the value was higher than the normal 4 percent for C class asteroids. Perhaps the higher value resulted from a mixture of bright frost on the surface, present simply because Chiron has not been close enough to the Sun to burn it off.

These ideas tie in to another type of study of Chiron. Dynamicists, using the laws of celestial mechanics, have tried to calculate the orbital history and future of Chiron. These calculations confirm that Chiron has not been in its present orbit for more than a tiny fraction of solar system history. The calculations show that Chiron closely approaches Saturn every few thousand years. Probably it acquired its present orbit after a close encounter with Saturn, perhaps tens of thousands of years ago. Eventually it will have such a close encounter that its orbit will change again, just as *Voyager 1* and *Voyager 2* were flung onto new orbits as they passed close to Saturn.

Dynamicists cannot calculate exactly the earlier orbit or the future orbital history after the next Saturn encounter, because the results vary greatly with only the tiniest changes in the approach conditions. The most likely future would have Chiron flung on a wildly new orbit that might take it back into long-term storage in the Oort cloud. But it also could be deflected toward the inner solar system, becoming more spectacular than any recorded comet.

Most comet nuclei have diameters of a few miles. The nucleus of Halley's Comet measured about 5 by 10 miles in extent. Based on the best measurements, including one obtained in early 1990 at Mauna Kea, Chiron is probably 110 to 160 miles in diameter. If we neglect asteroid 1 Ceres with its thin cloud of molecules, this makes Chiron the biggest well-observed comet nucleus in the solar system!

Chiron, Ceres, and probably even Phobos are changing our view of solar system relationships: the outer solar system interplanetary bodies, including not only remote asteroids but also comets, all turn out to have dark surfaces. Probably this dark material is a mixture of black carbonaceous minerals and bright ices. Some may have a higher proportion of ice in their surface material and hence a lighter color. Others may have had most of the ice burned out of their surface material, leaving only a residue of very black dust on the surface. Of these objects, "comets" may be merely the ones with a larger amount of ice, or with ice close enough to the surface that they can sublime, blow off dust, and produce a coma and tail at their given solar distance. Others may be basically similar in composition and appearance but temporarily or permanently inactive.

During the 1990s astronomers will track Chiron's behavior to test some of these ideas. Chiron is slowly approaching its 1996 perihelion just inside Saturn's orbit, some 8.5 AU from the Sun. Will it brighten dramatically by that time? Will the outbursts continue at ever-more-frequent intervals? Will it develop a stronger coma? Presently Chiron softly glows at about 16th magnitude, and it is unlikely ever to become a prominent object in your backyard telescope. Still, this mysterious denizen of the deep will bring many valuable lessons to planetary astronomers. The most important lesson has already come: never again will astronomers think about asteroids and comets in quite the same way. □

William K. Hartmann is a senior scientist at the Planetary Science Institute in Tucson and is known for his work on asteroids, comets, and craters. He is an avid painter and writer, having published Desert Heart: Chronicles of the Sonoran Desert (Fisher Books, 1989).

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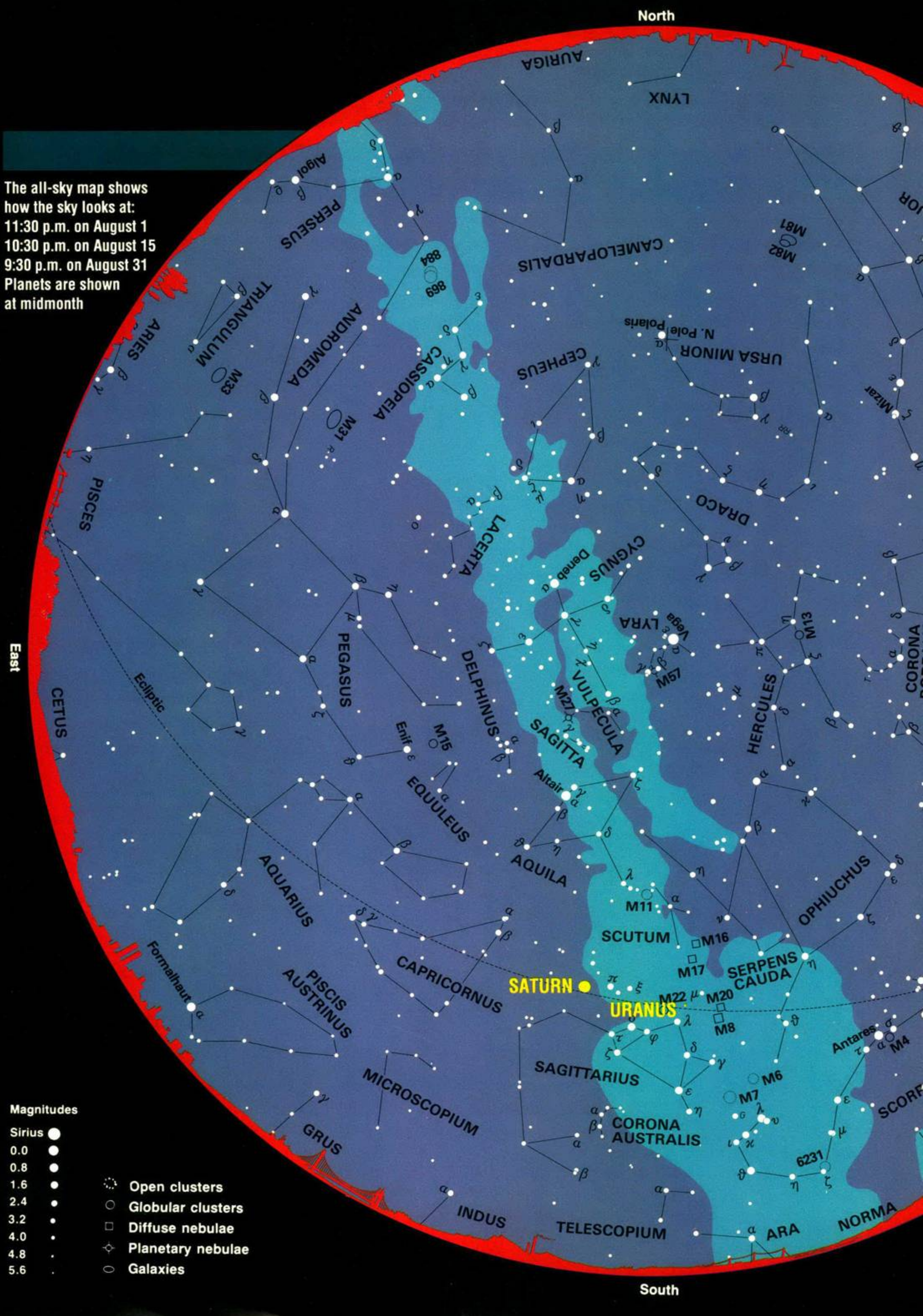
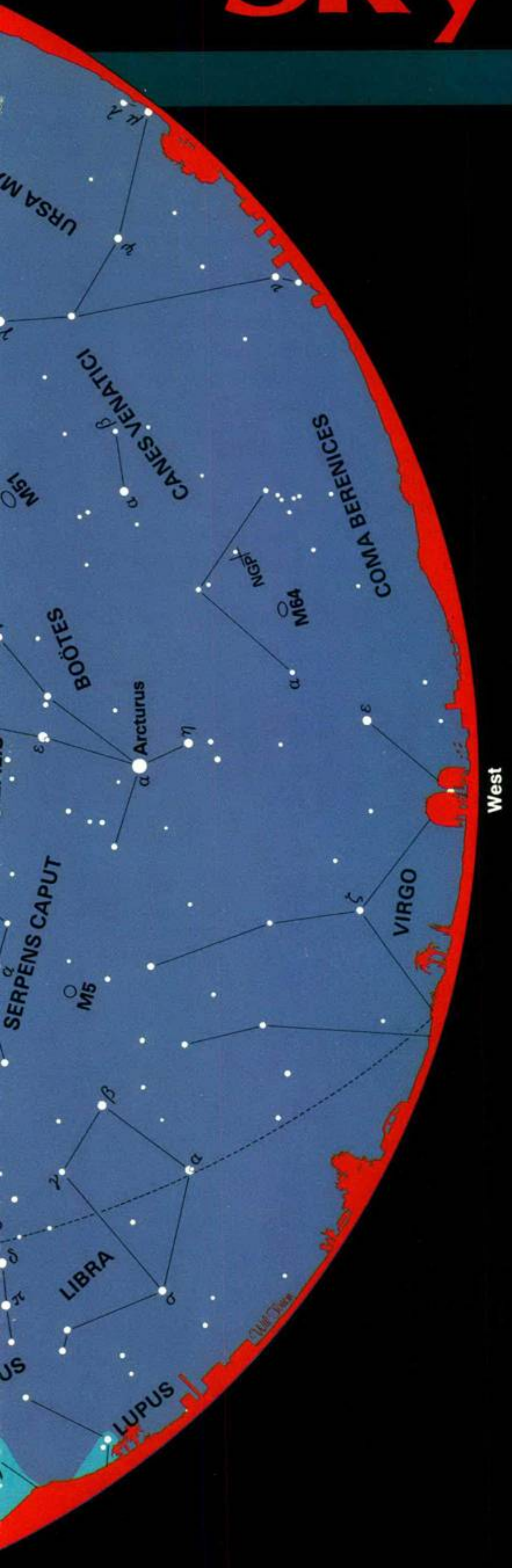


The all-sky map shows how the sky looks at:
11:30 p.m. on August 1
10:30 p.m. on August 15
9:30 p.m. on August 31
Planets are shown at midmonth

North
South
East
AURIGA
LYNX
PERSEUS
Algol
CAMELOPARDALIS
M81
M82
884
869
TRIANGULUM
ARIES
M33
ANDROMEDA
CASSIOPEIA
M31
CEPHEUS
N. Pole Polaris
URSA MINOR
Mizar
PISCES
LACERTA
DRACO
CYGNUS
Deneb
LYRA
Vega
M57
M13
HERCULES
CORONA
PEGASUS
DELPHINUS
VULPECULA
M27
SAGITTA
Ecliptic
CETUS
Enif
M15
EQUULEUS
Altair
AQUILA
AQUARIUS
M11
SCUTUM
M16
M17
OPHIUCHUS
SERPENS CAUDA
SATURN
URANUS
M22
M20
M8
CAPRICORNUS
PISCIS AUSTRINUS
Formalhaut
SAGITTARIUS
M6
M7
Antares
M4
SCORP
MICROSCOPIUM
CORONA AUSTRALIS
GRUS
6231
INDUS
TELESCOPIUM
ARA
NORMA
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

August 1990



LUNAR ECLIPSE ON AUGUST 6

The Moon passes partially into Earth's dark umbral shadow on August 6, and at maximum 68 percent of the lunar disk is immersed in darkness. Observers on the West Coast of North America can see the beginning of the eclipse before the Moon sets on the morning of August 6, while those in Hawaii, eastern Asia, and Oceania can see the entire event.

A STRIKING PAIR OF PLANETS

Venus and Jupiter are stunning in this month's morning sky. The two begin the month separated by about 10°, but they quickly close the gap and by August 12 and 13 appear within 0.5° of each other. The crescent Moon adds to the scene on August 18, when it occults Jupiter for observers in most of the United States and Canada.

THE MOON OCCULTS THE PLEIADES

On the morning of August 14 the Moon passes through the Pleiades star cluster, occulting several of the cluster's stars. The entire event is visible from the eastern part of North America, while in the western part viewers can see only the later stages of the occultation.

Calendar of Events

1 The Moon passes 0.1° north of Antares, 5 a.m. EDT

4 The Moon passes 1.6° south of Saturn, 2 p.m. EDT

6 Full Moon is at 10:19 a.m. EDT; partial lunar eclipse

11 Mercury is at greatest eastern elongation (27°)

12 Perseid meteor shower is at its peak
Venus passes 0.04° north of Jupiter, 7 p.m. EDT

13 Last Quarter Moon is at 11:54 a.m. EDT

14 The Pleiades are occulted by the Moon, 2 a.m. EDT
Harmonia is at opposition

15 The Moon is at perigee (229,333 miles from Earth), 6:09 a.m. EDT

18 Jupiter is occulted by the Moon, 8 a.m. EDT
The Moon passes 0.5° south of Venus, 8 p.m. EDT

20 New Moon is at 8:39 a.m. EDT
Amphitrite is at opposition
Ceres is in conjunction with the Sun

22 The Moon passes 0.2° south of Mercury, 8 a.m. EDT

27 The Moon is at apogee (251,170 miles from Earth), 10:58 p.m. EDT

28 First Quarter Moon is at 3:34 a.m. EDT
The Moon passes 0.2° north of Antares, 1 p.m. EDT

31 The Moon passes 1.7° south of Saturn, 8 p.m. EDT

Eye on the Sky by *Deborah Byrd*

WESTERN UNITED STATES TO SEE ECLIPSE OF MOON

On the morning of August 6, the Moon passes through the northern part of Earth's shadow and a partial lunar eclipse occurs. In the Western Hemisphere this eclipse is best seen from Hawaii and southwestern Alaska, though the beginning of the eclipse's umbral phase is also visible from the West Coast of North America. Observers in eastern Asia, Japan, Australia, and New Zealand can see the entire eclipse.

Earth's shadow has two parts, a dark central region called the umbra and a lighter surrounding region called the penumbra. In every lunar eclipse the Moon slides first into the penumbral shadow, but a penumbral eclipse is so subtle that it is difficult to discern even when you're staring right at it. The penumbral eclipse that covers the western half of North America on August 6 will test the skills of even the most perceptive observers. This one is especially challenging to see because it begins not long before moonset, when the Moon is low in the west-southwest and the sky is starting to grow brighter with the approach of dawn.

The situation is better on the West Coast of North America, where the umbral eclipse begins before the Moon sets. If you have an unobstructed western horizon you should see a small dark "bite" taken out of the Full Moon's limb in the final half hour before the Moon sets. For observers in Hawaii and southwestern Alaska the Moon remains above the horizon until after mid-eclipse, which occurs at 4:12 a.m. local time in Hawaii. At that time 68 percent of the Moon's face is immersed in Earth's umbral shadow.

A PARTIALLY ECLIPSED MOON sets over England's Chiltern Hills in Mark Payne-Gill's photo of the August 17, 1989, lunar eclipse (above). Similar circumstances should provide observers on the West Coast of North America with an excellent view of the partial lunar eclipse on August 6 (below).

VENUS AND JUPITER AN EYE-CATCHING TWOSOME

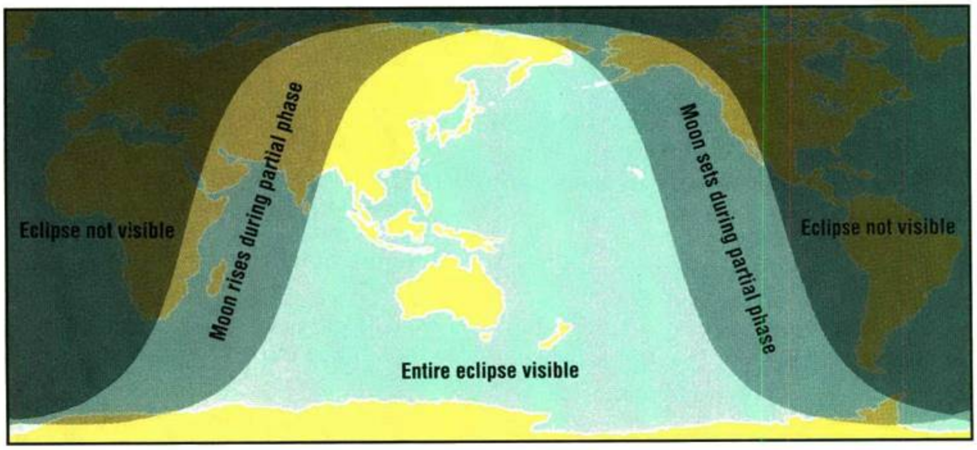
As if to compensate for the lunar eclipse which many of us won't be able to see, the two brightest planets put on a dramatic show low in the morning sky this month.

You can start looking for Venus and Jupiter as soon as August begins. Venus is easier to see, shining brilliantly at magnitude –3.9 low in the east-northeast. Jupiter, at magnitude –1.8, is not only fainter than Venus, it is also lower in the predawn sky. To the left of Venus, however, are two stars — Castor and Pollux — that can help you locate Jupiter. An imaginary line drawn between the two and extended toward the horizon leads right to Jupiter.

By the start of the second week of August, Jupiter is clearly visible below Venus in the east-northeast. That's when the drama begins in earnest, as the two dazzling planets edge closer together with each passing day. They are closest on the mornings of August 12 and 13, when they are separated by just 0.5° — one Moon-diameter.

This remarkable conjunction is best seen from East Asia and Japan. From there Venus and Jupiter appear only 0.04° apart before sunrise on the 13th. Not only is this the closest conjunction of any two planets in 1990, it is the closest observable conjunction between Venus and Jupiter — our two brightest planets — between 1949 and 2082.

After the 13th, Venus and Jupiter slowly pull away from one another. Even so, keep watching, and be sure to look on the morning of August 18 when the waning crescent Moon lies next to Jupiter while Venus lies just 5° below that pair.


Eclipse not visible
Moon rises during partial phase
Moon sets during partial phase
Eclipse not visible
Entire eclipse visible

SUMMER METEORS CONTINUE

The famous Perseid meteor shower peaks this year on August 12. The shower tends to build gradually toward this peak and then fall off more rapidly. Unfortunately, the waning gibbous Moon interferes with the peak of the Perseids in the prime viewing hours after midnight. The best time to view meteors this month is on the mornings of August 1 to 5, from the time the Moon sets in the wee hours until shortly before dawn. Not only can you see some early Perseids at this time, but you'll also catch the tail end of July's Delta Aquarid meteor shower.

AUGUST'S PLANETS

Saturn is only a couple of weeks past opposition as August begins, so it remains a prominent object throughout the month. At each nightfall the cream-colored planet appears low in the southeast, not far from the Teapot asterism in Sagittarius. It then wheels across the southern sky with Sagittarius throughout the night.

Although Saturn is the faintest of the bright planets, at magnitude 0.2 it is brighter than most of the stars in the summer sky. Even so, you'll enjoy your view of Saturn most if you observe it from under a dark sky. On a clear, moonless night the planet stands out prominently to the left of the glittering band of the summer Milky Way.

The next planet to rise is Mars, which pokes above the east-northeast horizon around midnight. By dawn it is high in the south. The ruddy planet has been in the morning sky all year, as its eastward motion against the background stars has kept it more or less in the same position relative to the Sun. But that will soon change.

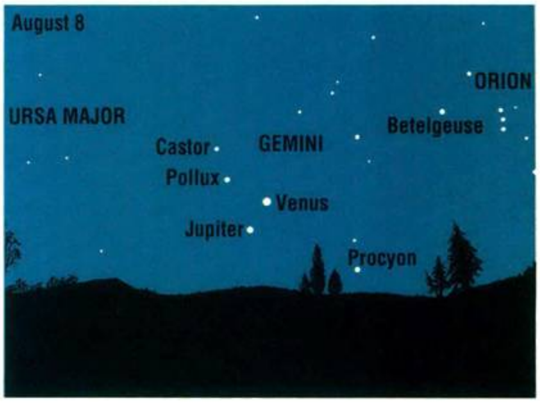
The first clue that something dramatic is about to happen is Mars' increasing brightness. During August the planet brightens noticeably from magnitude 0.0 to –0.4. That's because Earth is rapidly catching up to Mars in our faster orbit around the Sun. In November Earth will pass between Mars and the Sun, and the Red Planet will be brighter than it has been in over two years.

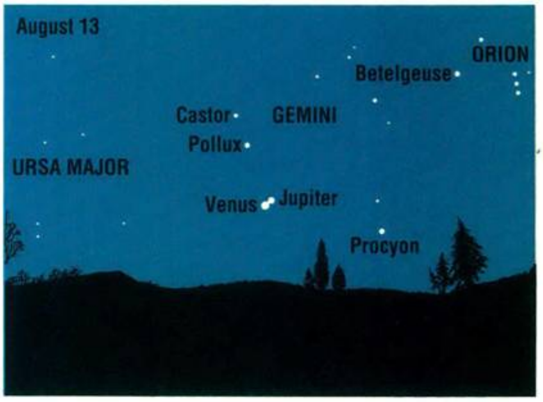
Venus has been a beacon low in our predawn sky for many months now. In August we see Venus rising in the east-northeast among the bright stars associated with the evening sky in winter. The planet is near Castor and Pollux in Gemini; it passes 7° south of Pollux on August 9 and is lined up with the two stars at mid-month.

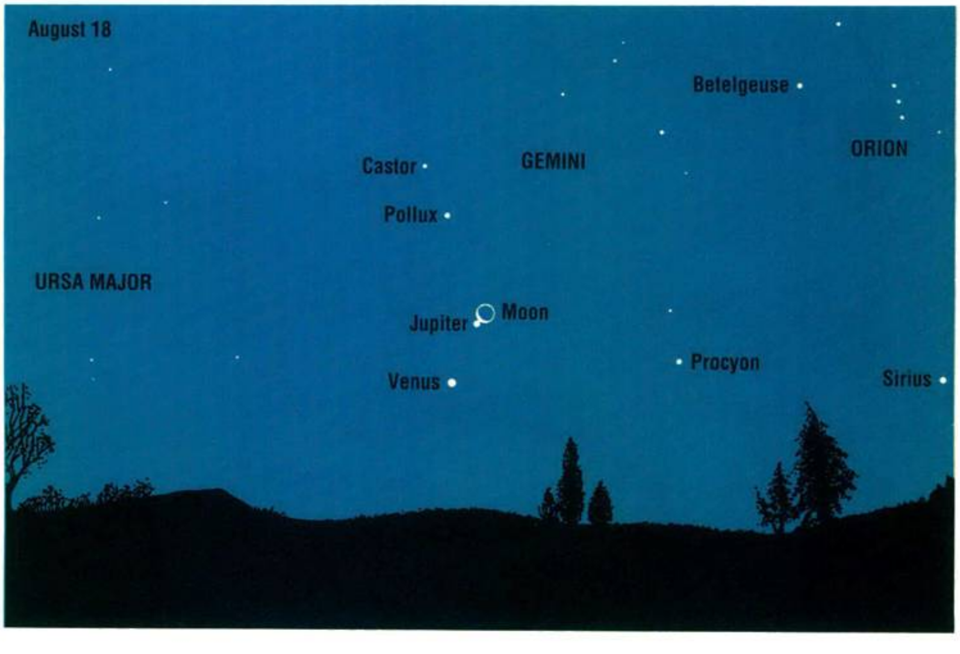
While Venus gradually sinks into the twilight glare this month, Jupiter, which is returning from being behind the Sun, climbs out of it. The two put on a grand show as they pass each other. From the Western Hemisphere the two are separated by only 0.5° on the mornings of August 12 and 13.

An equally striking scene greets early morning observers on August 18, when the waning crescent Moon is poised to slide past the two planets. To me, these groupings of very bright objects possess an almost spiritual quality. As seen from the western United States and western Canada, Jupiter disappears behind the Moon shortly before sunrise. (See Through the Eyepiece for details

KEEP YOUR EYES on Venus and Jupiter as they pass one another in the August morning sky. The two bright planets lie low in the east-northeast and are closest on August 12 and 13; the Moon joins the pair on the morning of August 18.







A PERSEID METEOR STREAKS across the sky during the 1981 Perseid shower. Photo by Dan and Nancy Ostergaard. This year's Perseid shower peaks on August 12, but the waning gibbous Moon will wash out many fainter meteors.

on observing this event.) Venus is occulted by the Moon eleven hours later, but the event is not visible from North America.

Mercury can be seen with some difficulty very low in the west after sunset in the first part of August. Try sweeping for the 0.0-magnitude planet with binoculars thirty minutes after sunset. Mercury lies about 4° southeast of the bright star Regulus when the month begins.

Mercury is at greatest elongation on August 11, when it lies 27° east of the Sun. It is the shallow angle of the ecliptic relative to the horizon that makes the planet hard to see this month.

AUGUST'S STARRY SKY

August is traditionally the best time to view the glittering arc of the summer Milky Way. This hazy bridge of stars, almost legendary to city dwellers but obvious to those who live in the country, stretches between horizons in the evening hours this month. It is easiest to see when the Moon is gone from the sky. This August, that would be from shortly before mid-month until a few days before the month ends.

While contemplating this vast sweep of stars, it's hard not to think BIG. After all, we see the Milky Way in our sky while looking edgewise into the disk of our galaxy, a huge structure some 100,000 light-years in diameter that contains hundreds of billions of stars.

Yet there is a little constellation buried in the Milky Way whose very smallness is its charm. Sagitta lies north of Aquila the Eagle and south of Cygnus the Swan. If you know the famous asterism in Cygnus — called the Northern Cross — look for Sagitta near the foot of the Cross, about halfway between the stars Albireo and Altair.

Sagitta is composed of four stars arranged in a way that easily suggests an arrow pointing toward the east. How can you possibly find this tiny arrow in the vast arc of the Milky Way? It's easier than you might think. Although the arrow is very small, it is distinctively shaped, and very pretty.

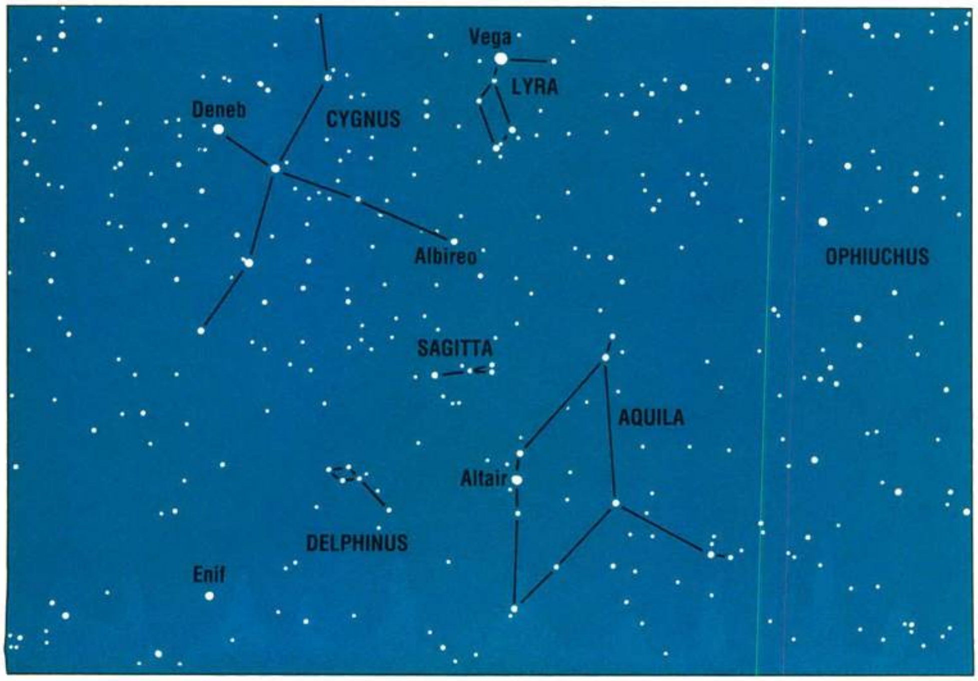
It's no surprise that this celestial arrow has a long history in the lore of the sky. On ancient star charts, Sagitta is occasionally shown as being held in a talon of the Eagle Aquila.

In its history of being regarded as a weapon, Sagitta is sometimes said to have been an arrow shot by Hercules toward Cygnus and Aquila. Apparently Hercules was not aiming very accurately in this case, however, because the arrow appears to fly harmlessly between the two celestial birds.

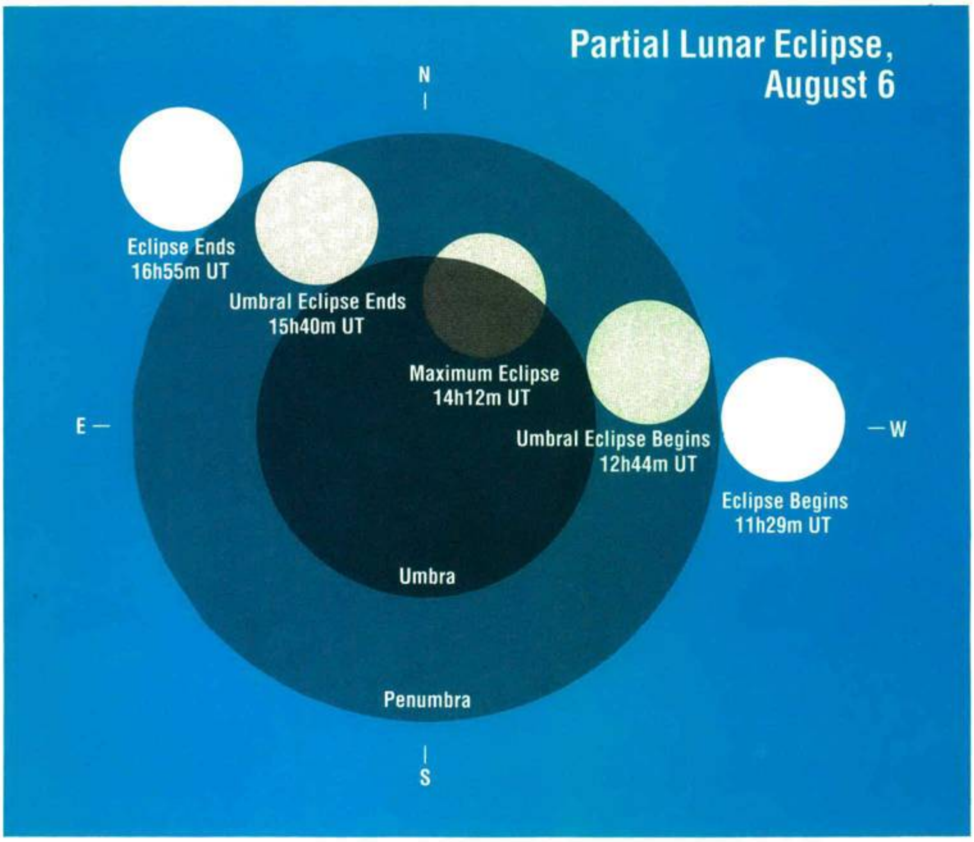
On the other hand, Sagitta has been said to be responsible for slaying Aquila, in legends where the eagle belonged to the king of the gods. The arrow has also been considered the shaft with which Apollo exterminated the Cyclops. And it has even been called Cupid's arrow, aimed at the hearts of prospective sweethearts! □

Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

SAGITTA THE ARROW is a small but distinctive constellation located high in the south late on August evenings. Look for this diminutive collection of 4th-magnitude stars nestled between Cygnus and Aquila.



THE MOON IN ECLIPSE


Partial Lunar Eclipse, August 6
N
E
W
S
Eclipse Ends 16h55m UT
Umbral Eclipse Ends 15h40m UT
Maximum Eclipse 14h12m UT
Umbral Eclipse Begins 12h44m UT
Eclipse Begins 11h29m UT
Umbra
Penumbra

THE MOON PLUNGES into Earth's umbral shadow at 12h44m UT on August 6 and is more than two-thirds immersed at maximum eclipse 88 minutes later. Use the table to track Earth's shadow as it traverses many of the lunar craters. (All times are in UT; subtract 7 hours to convert to PDT, 10 hours for local time in Hawaii.)

The Moon spends much of the month occulting nearly every bright celestial object in sight, so it seems only appropriate that the Moon itself is occulted in August. On August 6 Earth passes between the Sun and Moon, occulting the Moon as seen from the Sun and treating earthbound observers to a lunar eclipse. The Moon does not pass completely into the umbra, the darkest part of Earth's shadow, so we see only a partial lunar eclipse.

Observers on North America's West Coast get to see the early stages of the eclipse before the Moon sets and the Sun rises. Meanwhile observers in Hawaii, eastern Asia, and Oceania can see the event in its entirety. (The map on page 52 shows where the eclipse is visible, and the diagram at right gives the times of the eclipse.) At mid-eclipse 68 percent of the Moon is darkened by Earth's umbral shadow.

There are a variety of ways to observe and record a lunar eclipse, from sitting in a recliner and viewing it with a pair of binoculars to putting together a high-tech photographic or video rig. Although lunar eclipses happen often enough that some observers adopt a "ho-hum" attitude toward them, they can be among the most beautiful of celestial events.

The major spectacle during a lunar eclipse is the color of the Moon when it is in Earth's shadow. If Earth had no atmosphere, lunar eclipses would be rather boring events (though we likely would not be here to be bored by them). Earth's umbral shadow would be perfectly sharp, and the Moon would disappear completely as it passed through the shadow.

But Earth does have an atmosphere, and some of the light passing through it at the terminator (the sunrise-sunset line) is refracted, or bent, into the shadow. If it were not for the wave nature of light, this filtered sunlight would turn the shadow gray. However, scattering by tiny dust particles in Earth's atmosphere effectively removes the shorter-wavelength blue and green light and lets more of the longer-wavelength yellow and red light through to color the eclipsed Moon.

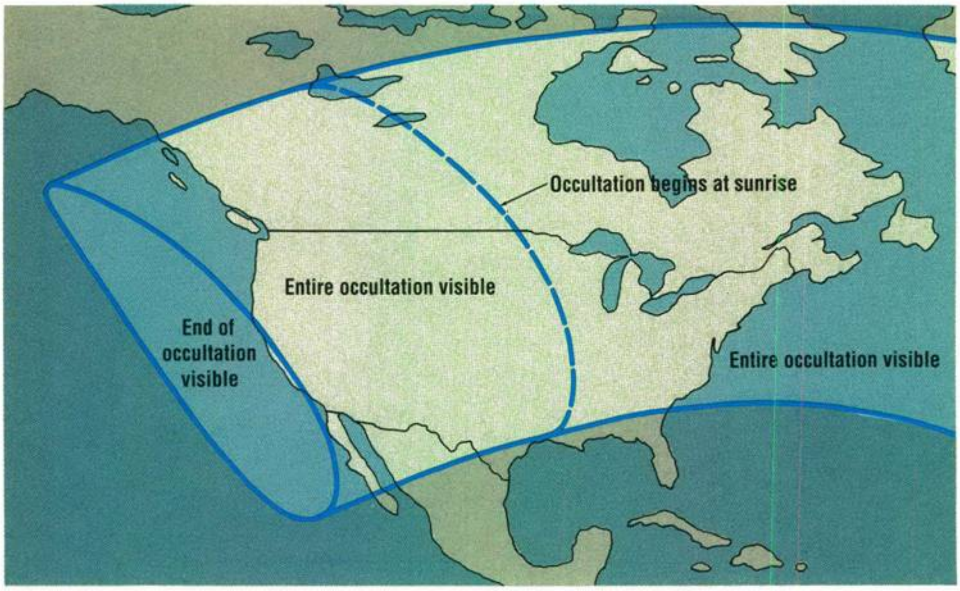
The eclipsed Moon's color is one of the reasons that lunar eclipses are so photogenic. You can get beautiful photographs of the eclipse by mounting an SLR camera on a tripod and photographing right through the low-power eyepiece of your telescope. Use fast film, set the camera lens wide open, focus your camera and telescope for infinity, and use your camera's light meter to determine the exposure. You can use the same technique to get impressive results from a video camera.

Although perhaps not as interesting as the Moon's color, an entertaining mini-spectacle to watch during the eclipse is Earth's shadow covering and uncovering craters. To view the shadow as it crosses a crater, use the highest power that your aperture and the seeing allows. The table at right lists many prominent craters and gives for each the

CRATER CROSSINGS

Crater	Immersion Time	Emersion Time
Grimaldi	12h55m	14h36m
Billy	12h57m	14h48m
Campanus	13h02m	15h05m
Tycho	13h06m	15h19m
Kepler	13h17m	14h33m
Copernicus	13h30m	14h38m
Aristarchus	13h37m	14h07m
Pytheas	13h47m	14h19m
Dionysius	13h47m	15h00m
Goclenius	13h50m	15h22m
Langrenus	13h57m	15h24m
Manilius	13h57m	14h40m
Menelaus	14h06m	14h37m
Taruntius	14h06m	15h05m
Plinius	14h10m	14h41m

predicted time when Earth's shadow enters the crater's center (immersion) and exits the crater's center (emersion).


Occultation begins at sunrise
Entire occultation visible
End of occultation visible
Entire occultation visible

JUPITER DISAPPEARS behind the Moon for observers throughout most of North America on the morning of August 18. The entire occultation is visible east of the oval area, but it occurs after sunrise to the east of the dashed line.

A JUPITER OCCULTATION

On the morning of August 18, the 5-percent-lit crescent Moon occults Jupiter and that planet's Galilean satellites. All or most of this spectacular event is visible to backyard astronomers in the United States and Canada, except for those in the extreme southeastern United States, northern Canada, Alaska, and Hawaii. The view should be better from the western half of North America than from the eastern half, where the occultation occurs after sunrise and you'll need a telescope to observe it. (See the map at left for specifics on the occultation's observability.)

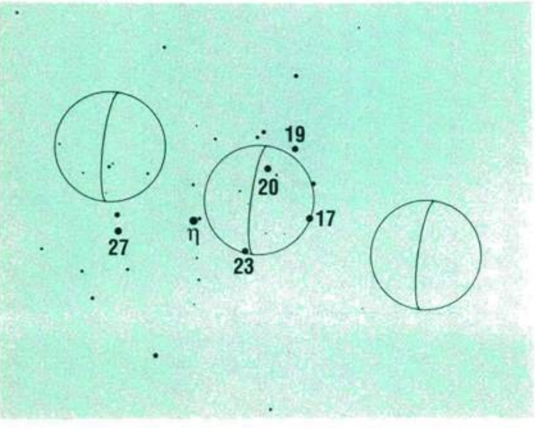
One of the more interesting aspects of the occultation you'll see in a telescope is the contrast between the Moon's generally gray-green color and Jupiter's cream-colored zones and ocher belts. This is particularly impressive just as the Moon's limb gobbles up the gas giant's disk. Because both objects are plenty bright, you can use as high a power as the seeing will stand.

THE MOON CONCEALS THE SEVEN SISTERS

Although observers in the eastern and central regions of North America don't get the best view of the Jupiter occultation, they can witness another exciting occultation on the morning of August 14 when the Moon passes through the open star cluster M45, the Pleiades or Seven Sisters. Observers on the West Coast don't have as good a view — the occultation has already begun by the time the Moon rises — but they can still watch the Moon exit the cluster and enjoy the sight of the Moon poised on the cluster's eastern edge. Because the Moon is now taking a more central path through the Pleiades than it did during the series of occultations last year, more stars are occulted and there is more action to observe.

The Moon traverses the Pleiades a day past Last Quarter phase, so the sunlit side of the 43-percent-lit waning crescent leads the way. Stars disappear behind the lit portion of the Moon and then "pop" out of nothing as they emerge from behind the Moon's dark limb.

PASSING THROUGH THE PLEIADES on the morning of August 14, a fat crescent Moon occults the cluster for observers in most of eastern and central North America. This view shows the Moon at 90-minute intervals beginning at 12:30 a.m. EDT (right) as seen from Boston.



TELESCOPIC PLANETS

Mercury can be seen in the evening sky this month, but it never gets more than 5° above the western horizon thirty minutes after sunset. It is easiest to see around August 11, when the innermost planet is at greatest eastern elongation and lies 27° from the Sun. Unfortunately, those 27° don't translate into much altitude. On that night Mercury shines at magnitude 0.4 and shows a 49-percent-lit disk measuring 7.5" across. You'll get a much better view of the elusive planet if you wait until September, when it puts on its best morning apparition of the year.

Venus makes a great attempt at occulting Jupiter on August 12/13. At closest approach the two pass within 0.04° of each other, but that is only visible in the Eastern Hemisphere. Those of us in the Western

Hemisphere must be content to observe the pair on the mornings of the 12th and 13th, when they are about 0.5° apart.

You can keep Venus and Jupiter in the same field of view by using an eyepiece that yields 50x to 100x. Venus shows a 10.7"-diameter disk that is 93 percent illuminated, while Jupiter appears three times larger than that with a 31.9"-diameter disk. Although it appears smaller, Venus is easily the brighter of the two, with a surface brightness sixty times greater than Jupiter's and an overall brightness seven times greater. Also be sure to compare the pearly white cloud tops of Venus with the varied colors exhibited by the clouds in Jupiter's much more turbulent atmosphere.

Not to be outdone by Jupiter, Venus is occulted by the Moon just half a day after Jupiter gets the same treatment. Because it occurs half a day later, the event is best seen half a world away from North America — in the southern half of the Eastern Hemisphere. Just over a week before the Moon's encounter with Venus, an earthly visitor arrives at the planet. On August 10 the *Magellan* spacecraft completes a 15-month journey and goes into orbit around Earth's cloud-shrouded "twin," where it will radar map almost all of Venus' surface.

Although transitory events seem to dominate in August, Mars is worth watching all month. The Red Planet measures 9.1" across at the beginning of August and finishes the month with an equatorial diameter of 10.9". During the same period it brightens from magnitude 0.0 to –0.4. Mars also reaches quadrature this month, when it is 90° from the Sun in our sky, so we see as much as we can ever see of its nighttime hemisphere. Only 84 percent of Mars' Earth-facing hemisphere is lit in early August, and you should have no problem discerning the planet's distinctly gibbous shape.

Saturn is a fine early evening object in August. The ringed planet culminates — reaches its highest elevation in the sky — about an hour after twilight ends, and the seeing is usually better when an object is higher in the sky. This month Saturn shines at magnitude 0.2 with a disk that measures 18.1" across its equator and rings that span 41.3".

If the seeing is particularly good when you view Saturn, be sure to take a look at Uranus and Neptune. Uranus is a 5.6-magnitude object about an hour of right ascension west of Saturn and displays a blue-green disk 3.7" in diameter. Blue-gray Neptune lies halfway between Saturn and Uranus and has a 2.3"-diameter disk that shines at magnitude 7.9.

ASTEROIDS IN THE EYEPIECE

August finds asteroids 29 Amphitrite and 40 Harmonia sharing nearly the same patch of sky. The two objects are less than 7° apart near the border of Aquarius and Capricornus. Amphitrite, which reaches opposition on August 20, is half a magnitude brighter at magnitude 9.1 than Harmonia, which reaches opposition on August 14/15. ☐

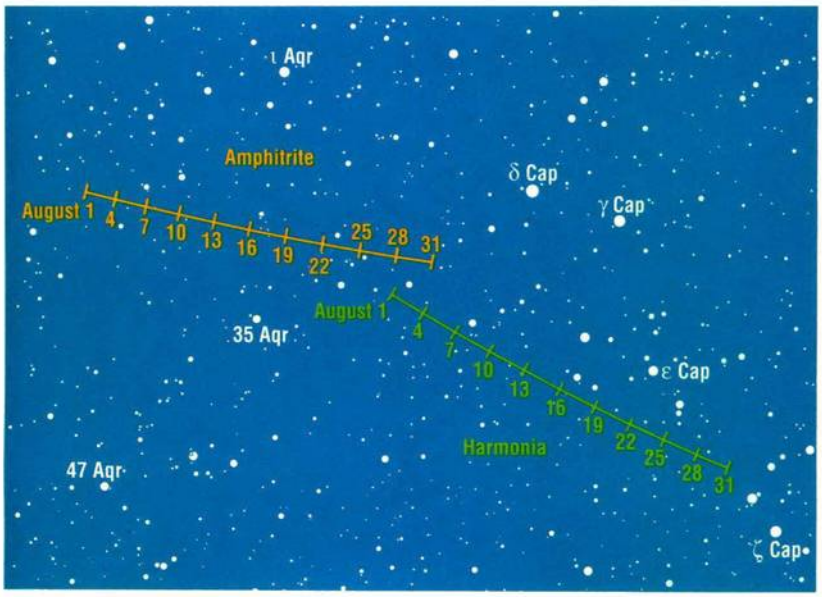
Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He is also a telescope and Frisbee nut, owning more than a few of both.

COORDINATES FOR AMPHITRITE

Date	R.A. (2000)	Dec.
Aug. 1	22h22.3m	–16°02'
Aug. 4	22h20.0m	–16°12'
Aug. 7	22h17.6m	–16°21'
Aug. 10	22h15.0m	–16°31'
Aug. 13	22h12.3m	–16°40'
Aug. 16	22h09.5m	–16°50'
Aug. 19	22h06.6m	–16°59'
Aug. 22	22h03.7m	–17°07'
Aug. 25	22h00.8m	–17°15'
Aug. 28	21h57.9m	–17°22'
Aug. 31	21h55.0m	–17°28'

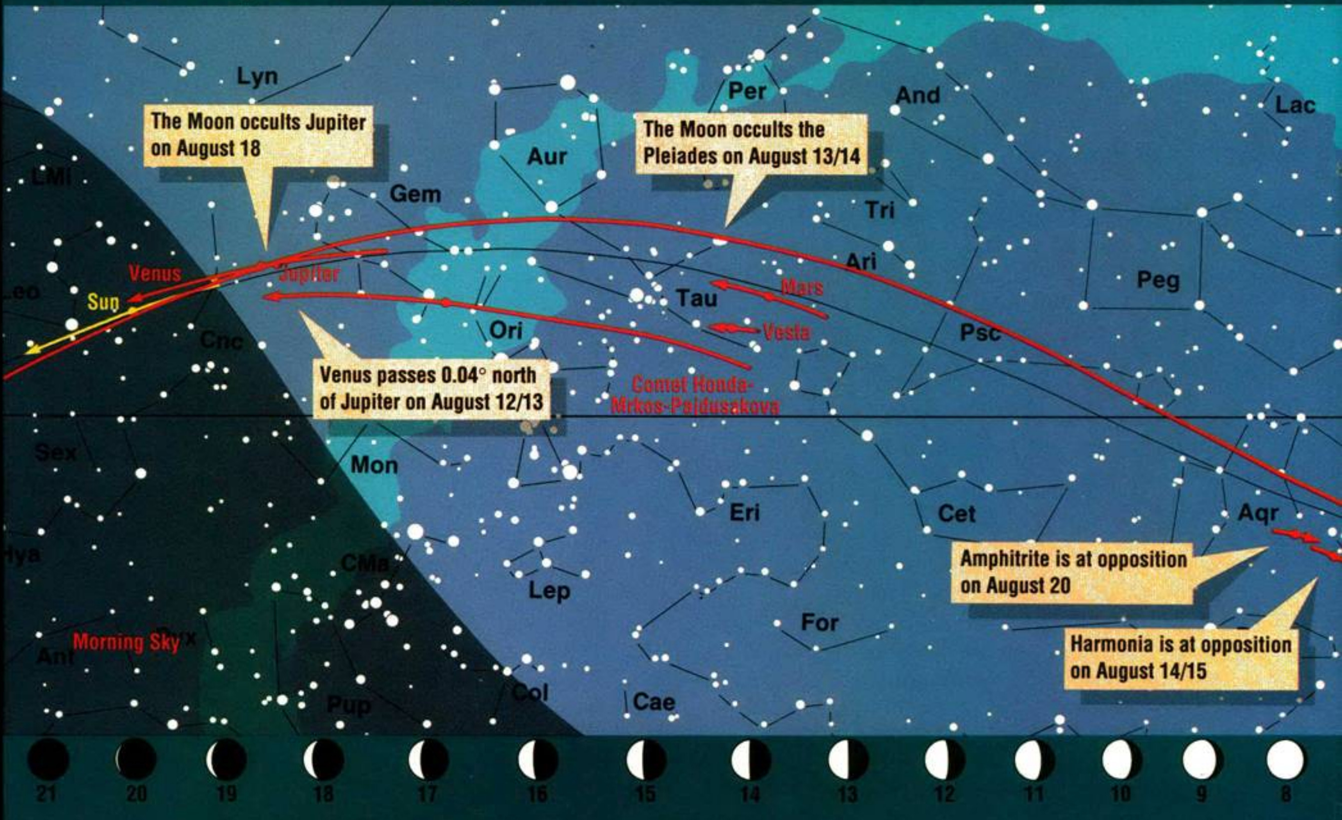
COORDINATES FOR HARMONIA

Date	R.A. (2000)	Dec.
Aug. 1	21h58.2m	–18°05'
Aug. 4	21h55.7m	–18°27'
Aug. 7	21h53.1m	–18°48'
Aug. 10	21h50.4m	–19°09'
Aug. 13	21h47.5m	–19°30'
Aug. 16	21h44.7m	–19°50'
Aug. 19	21h41.7m	–20°09'
Aug. 22	21h38.9m	–20°27'
Aug. 25	21h36.0m	–20°43'
Aug. 28	21h33.3m	–20°59'
Aug. 31	21h30.8m	–21°12'



AMPHITRITE AND HARMONIA reach opposition just a few degrees from each other near the Aquarius/Capricornus border in mid-August. Positions of the two asteroids are shown at 3 a.m. EDT (2 a.m. CDT, 1 a.m. MDT, and midnight PDT.)

The Solar System August 1990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Eri
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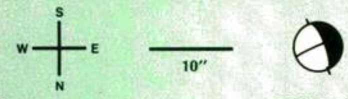
The Moon occults Jupiter on August 18

The Moon occults the Pleiades on August 13/14

Venus passes 0.04° north of Jupiter on August 12/13

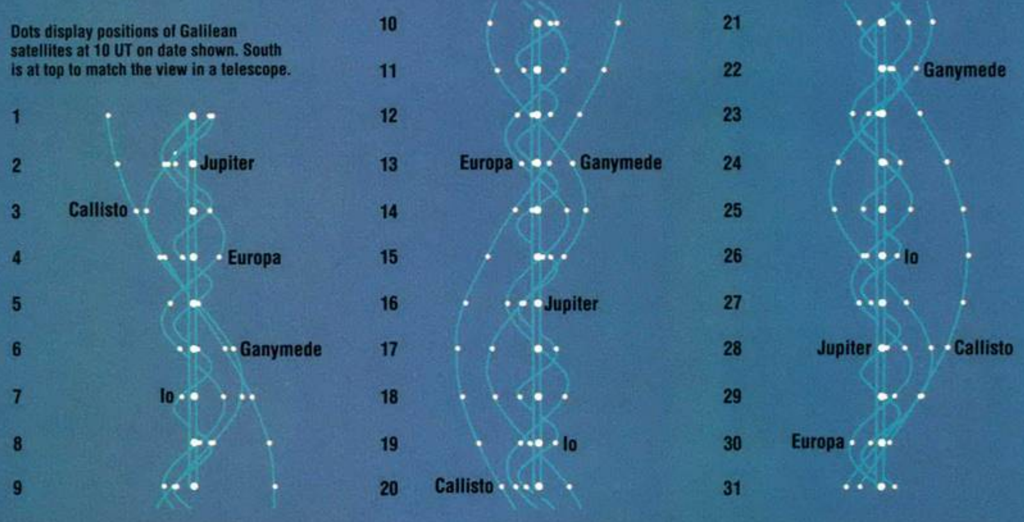
Amphitrite is at opposition on August 20

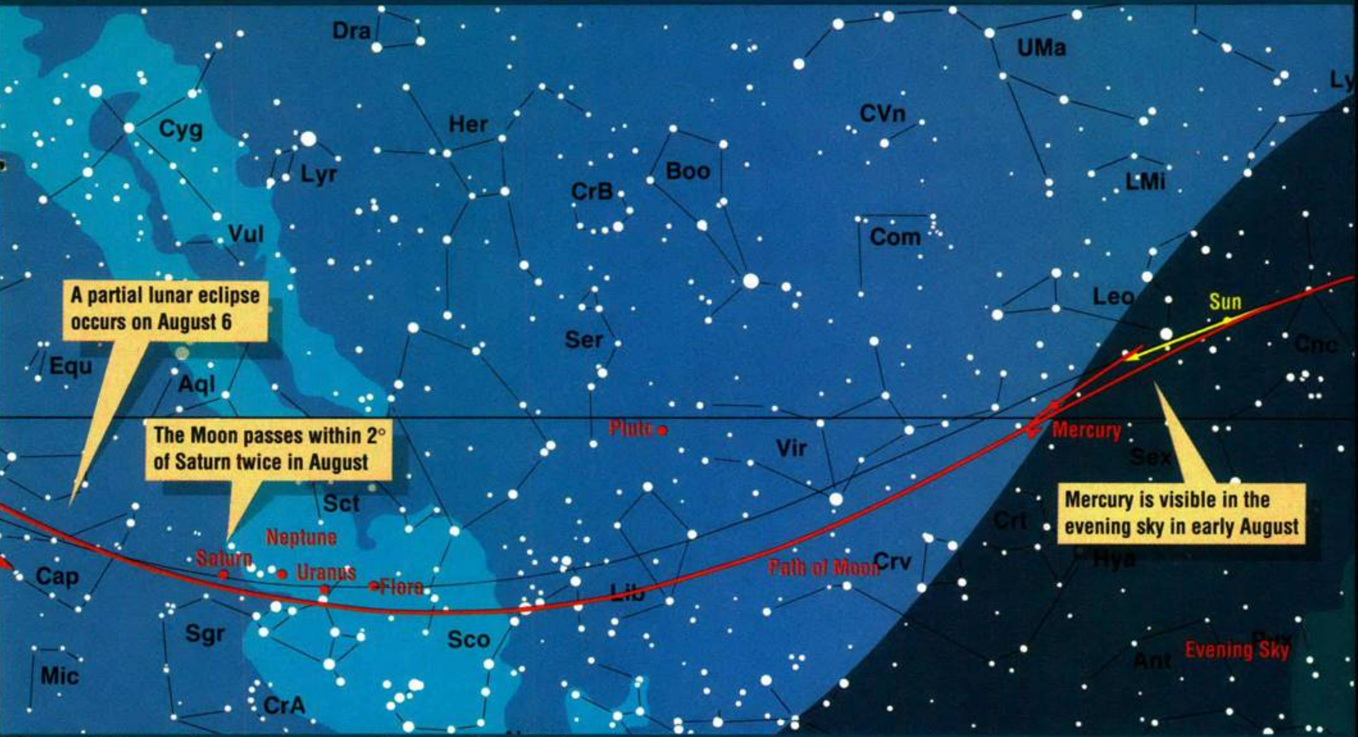
Harmonia is at opposition on August 14/15



Planet	MERCURY	MERCURY	VENUS	MARS
Date	August 1	August 31	August 15	August 15
Magnitude	0.0	+2.2	−3.9	−0.2
Angular Size	6.4"	10.3"	10.6"	9.9"
Illumination	65%	12%	93%	84%
Distance (AU) from Earth	1.053	0.652	1.573	0.946
Distance (AU) from Sun	0.450	0.418	0.720	1.396
Right Ascension (2000.0)	10h22.6m	11h24.5m	8h15.1m	3h17.3m
Declination (2000.0)	10°15'	−1°02'	20°14'	16°12'

Jupiter's Moons


Dots display positions of Galilean satellites at 10 UT on date shown. South is at top to match the view in a telescope.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Mercury
Vir
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Neptune
Saturn
Uranus
Flora
Path of Moon
Crv
Hya
Cap
Lib
Sgr
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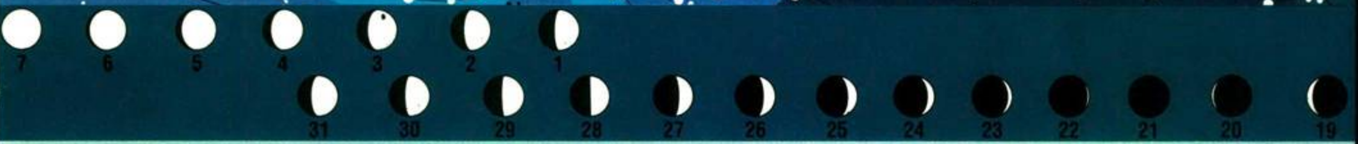
A partial lunar eclipse occurs on August 6

The Moon passes within 2° of Saturn twice in August

Mercury is visible in the evening sky in early August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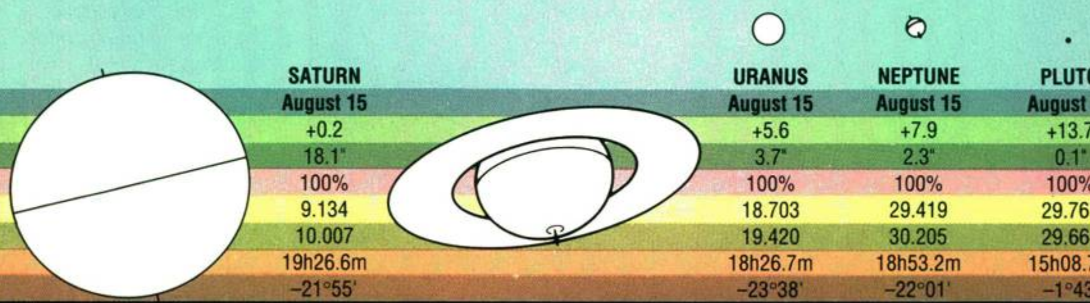
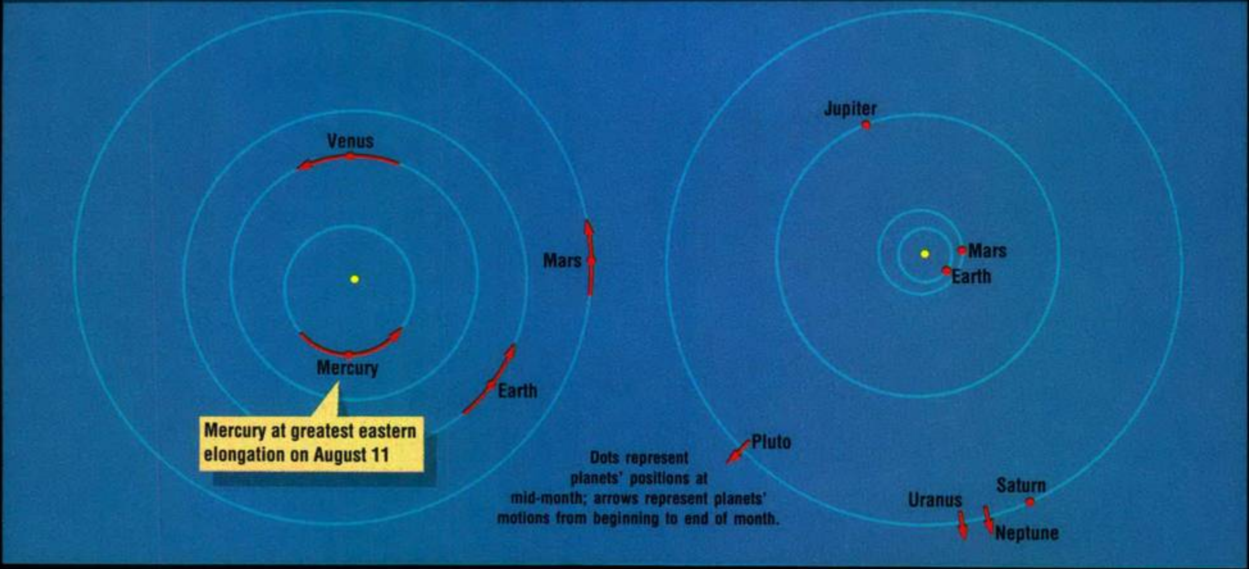


JUPITER August 15	SATURN August 15	URANUS August 15	NEPTUNE August 15	PLUTO August 15
−1.8	+0.2	+5.6	+7.9	+13.7
32.0"	18.1"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%
6.153	9.134	18.703	29.419	29.761
5.233	10.007	19.420	30.205	29.661
8h06.6m	19h26.6m	18h26.7m	18h53.2m	15h08.7m
20°33'	−21°55'	−23°38'	−22°01'	−1°43'

The Planets in Their Orbits


Venus
Mars
Mercury
Earth
Jupiter
Mars
Earth
Pluto
Uranus
Saturn
Neptune

Mercury at greatest eastern elongation on August 11

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Video Astronomy Comes of Age

Affordable, adaptable, and supersensitive, off-the-shelf camcorders are revolutionizing video astronomy.

by Michael Chibnik

The age of video astronomy has arrived. With an ordinary, off-the-shelf camcorder, a sturdy tripod, a handful of videotapes, and your telescope, you can record many of the night sky's wonders and enjoy viewing them over and over on your television. I've found that recording astronomy videos is tremendous fun because it keeps me involved with a project out under the stars and lets me relive the sights I've recorded in the comfort of my own living room. I especially appreciate participating in astronomy during cloudy or rainy nights.

Lunar Craters Messier A and B

All video images in this article are by David Brewer; still photography by M. Barlow Pepin.

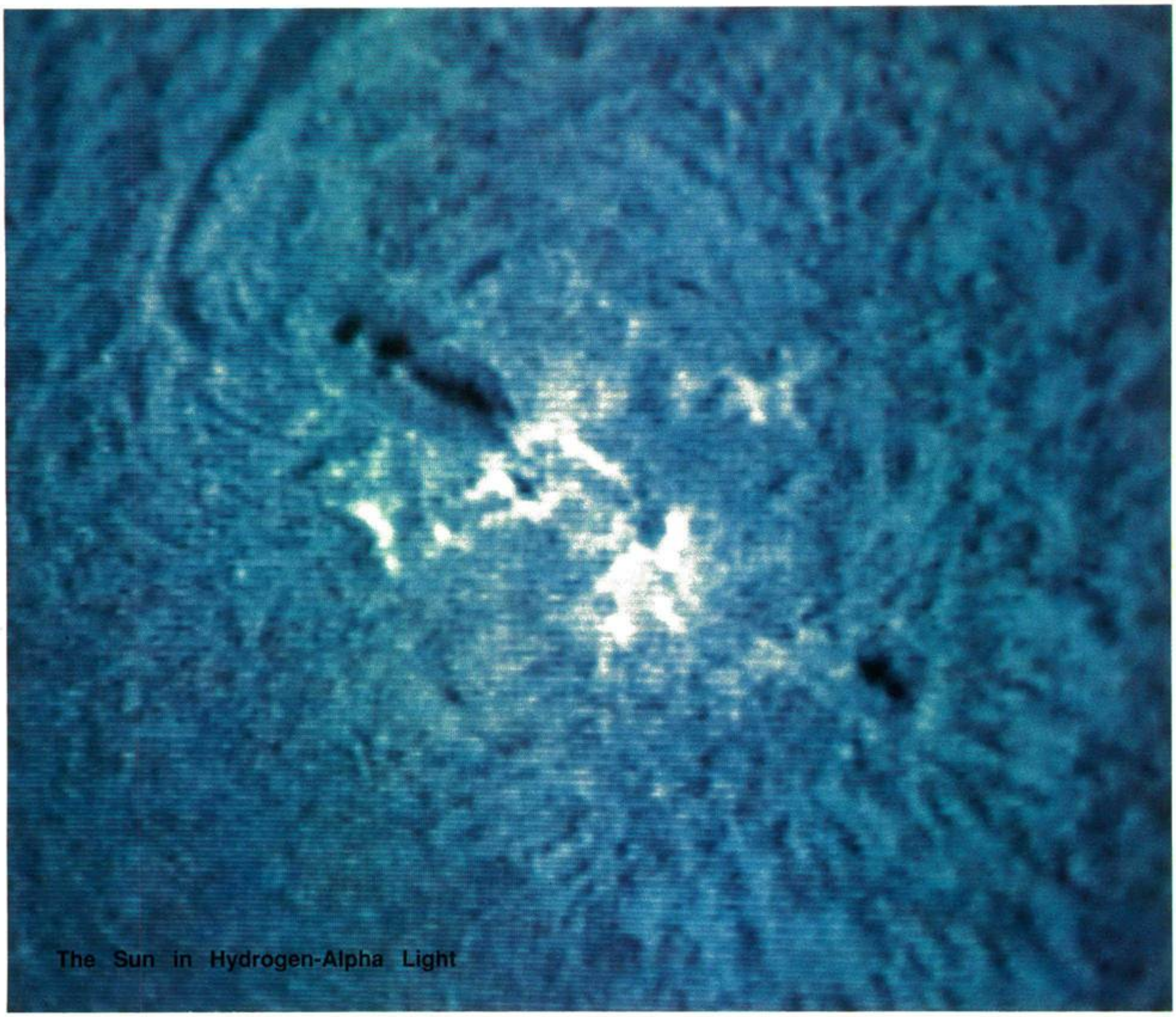
My discovery of video astronomy came about during the Mars opposition in 1988. I wanted to record the Red Planet but thought I had neither the equipment nor the experience to take good photographs of Mars. After nearly giving up, I resigned myself to experimenting with my camcorder, which has a permanently-mounted zoom lens.

To my delight, the afocal method produced exciting results. Afocal photography consists of placing the camcorder on a sturdy tripod and simply aiming the camcorder lens directly into an eyepiece at the back end of the telescope. At first I simply hand held my camcorder and aimed it through my 8-inch f/10 SCT. The images were shaky but looked promising. I discovered that if I mounted the camera on a tripod, I could produce acceptable results.

Getting Started in Astrovideography

The objects that can be recorded successfully with a camcorder are limited to those that are relatively bright. However, this includes a wide range of solar system objects. The Moon is an excellent subject to begin with. Lunar craters, highlands, walls, and rilles can all be recorded easily. Planets such as Mars, Jupiter, and Saturn show dusky markings, satellites, polar caps, and rings. You can record the changing phase of Venus. Elusive Mercury, Uranus, and Neptune show up as tiny glowing disks surrounded by stars. Outside of the solar system, bright double stars can be captured and, if your camcorder has a built-in charge-coupled device (CCD), you may record some of the brightest deep-sky objects.

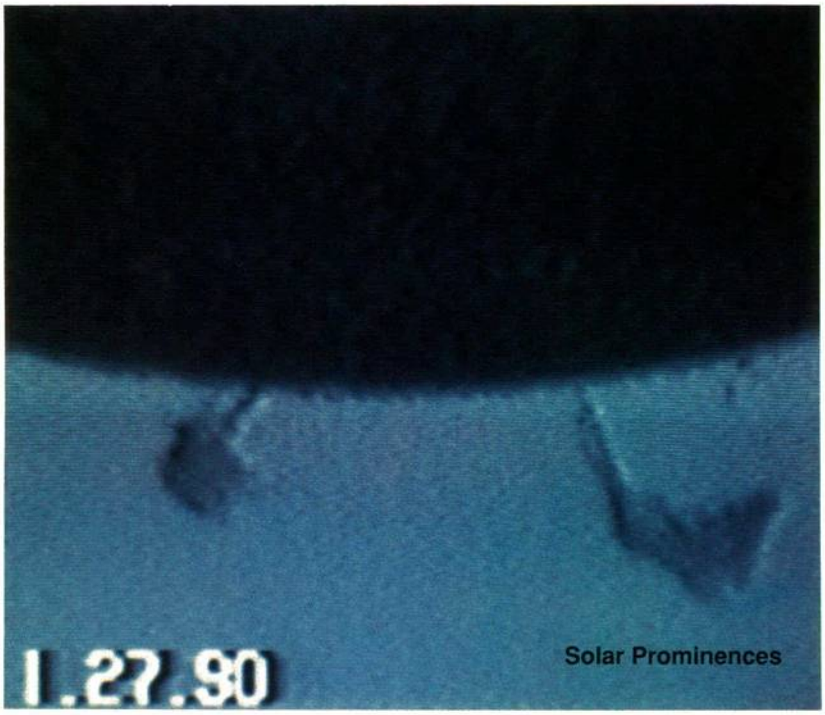
The most important step in beginning your adventure in video astronomy is choosing a camcorder. If you already have one, then try it for astronomy. However, if you're looking for a camcorder, you'll want to get


The Sun in Hydrogen-Alpha Light

one that not only records the kids at the beach but also does a good job with Saturn.

Ideally, you want the most sensitive camera you can get in order to record the faintest objects possible. I have a Panasonic PV-320, a camera with a sensitivity of 7 lux. (The lux scale is a rating of a camera's sensitivity; the lower the number, the more sensitive the camera.) When I bought my camcorder just a couple of years ago, the 7 lux rating was the best I could find. However, now many cameras use CCDs and boast lux ratings of 3, 2, or even 1. Get the lowest lux rating you can afford.

Raw sensitivity is not the only consideration when selecting a camera, however. After shopping around a bit and comparing with friends, I have found that different types of cameras behave differently when operating at low light levels. Different cameras also show image degradation to various degrees as light levels decrease. Cameras that utilize tubes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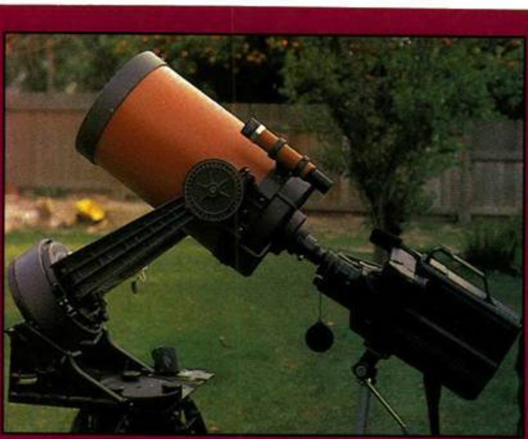
Solar Prominences



BASIC ASTRO-VIDEOGRAPHY begins by setting up your telescope and the camcorder on a sturdy tripod. Aim the camcorder directly into the telescope's eyepiece.

ZOOM THE CAMCORDER LENS all the way to the shortest focal length; this will provide the widest possible field and will capture the entire eyepiece field on tape.

FINE-TUNE IMAGE BRIGHTNESS if you need to by manipulating the camcorder's zoom lens control until the image shows the greatest detail.

SHOOT FOOTAGE as you would any other subject. Equipment photos by Michael Chibnik.

as sensing devices lose color sooner but still have reasonably sharp pictures as image intensity goes down. Cameras that use CCD chips as sensors have a higher initial sensitivity but show more noise as light levels decrease.

When comparing several types of CCD-chip cameras at the video store, I noticed that though several brands claimed the same sensitivity, some brands are better than others at low light levels. Some models had very noisy images, while in others the color rendition simply went to pieces at low light levels. To ensure you get a camera that's good for astronomy, explain to the salesperson what type of performance you are looking for. Ask them to let you take it to the darkest part of the store to test its low light level operation.

Both tube and CCD cameras create focused images on a sensitized matrix made up of lines, but there the similarity ends. Deciding what's best for you requires learning the basics of how each type works. Tube-type cameras have been used for television from the beginning. Modern image tubes go by trade names like Nuvicon, Saticon, and Vidicon. No matter what they are called, however, all image tubes work in a similar way.

The tubes operate by sending an image through a precision glass faceplate and focusing it on a light-sensitive screen called the target. Light that strikes the target changes the electrical charge and is recorded as current. An electron gun lies at the opposite end of the tube. The gun emits a beam of electrons that sweeps across the surface of the target in the same manner as the beam of electrons in your television. The gun scans its beam along the target one line at a time to record an overall image.

In normal television, scanning occurs on every other line of the image, so the process must be repeated to generate a complete picture. Scanning takes place at a rate of thirty times per second. The scanning electron beam generates an electric video signal that is amplified and added to other electric signals containing horizontal and vertical information.

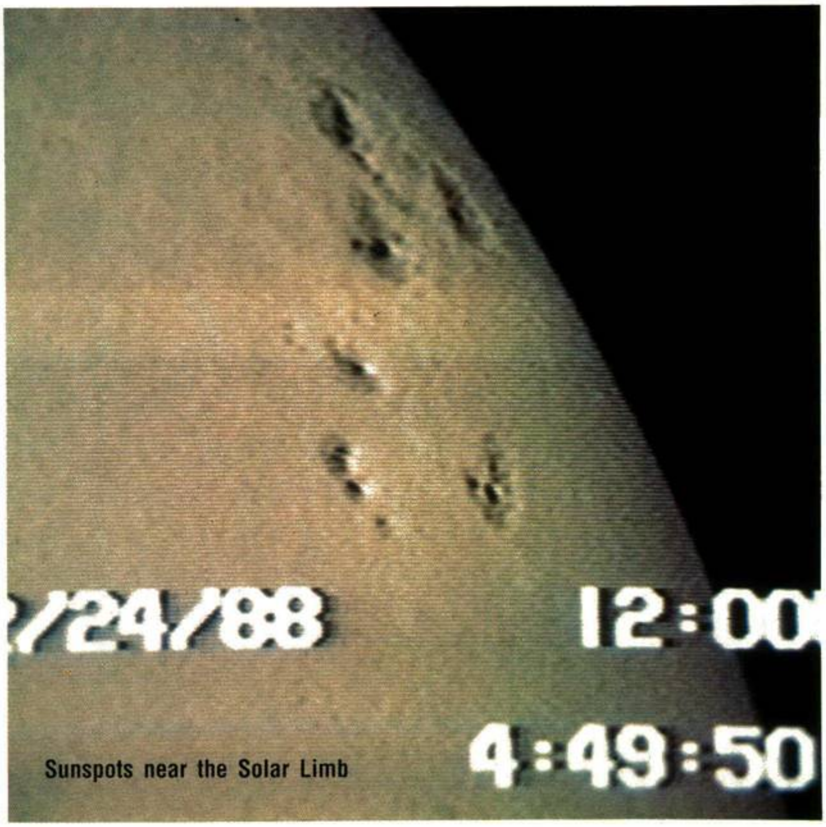
Until recently, most camcorders utilized the tube design because tubes were superior in resolution, sensitivity, color definition, and even price relative to other alternatives. However, the *recent explosion* of microchip technology has taken over and virtually eliminated tube cameras from the home market. Solid-state video sensors called charge-coupled devices or metal oxide semiconductor (MOS) chips employ the surface of a crystalline piece of silicon on which hundreds of horizontal lines of submicroscopic photocells sense light.

In CCD and MOS technology, the horizontal lines are electrically tied in series. When a CCD camera takes a picture every thirtieth of a second, light builds up a small electrical charge in each of the photocells. At the end of the thirtieth-second "integration," the cells dump their charges in a manner analogous to little electrical buckets. When you "read-out" the image, the first bucket sends its electrical charge off the chip. Simultaneously, the bucket next to the first one dumps its charge into the first one, the third one dumps into the second, and so on, all the way back to the end. This process is repeated until the charge of the last cell on a scan line has moved off the chip. Line after line of the CCD chip is scanned this way until the entire image has moved off the chip, creating a signal that can be recorded and then reconstructed on a television screen.

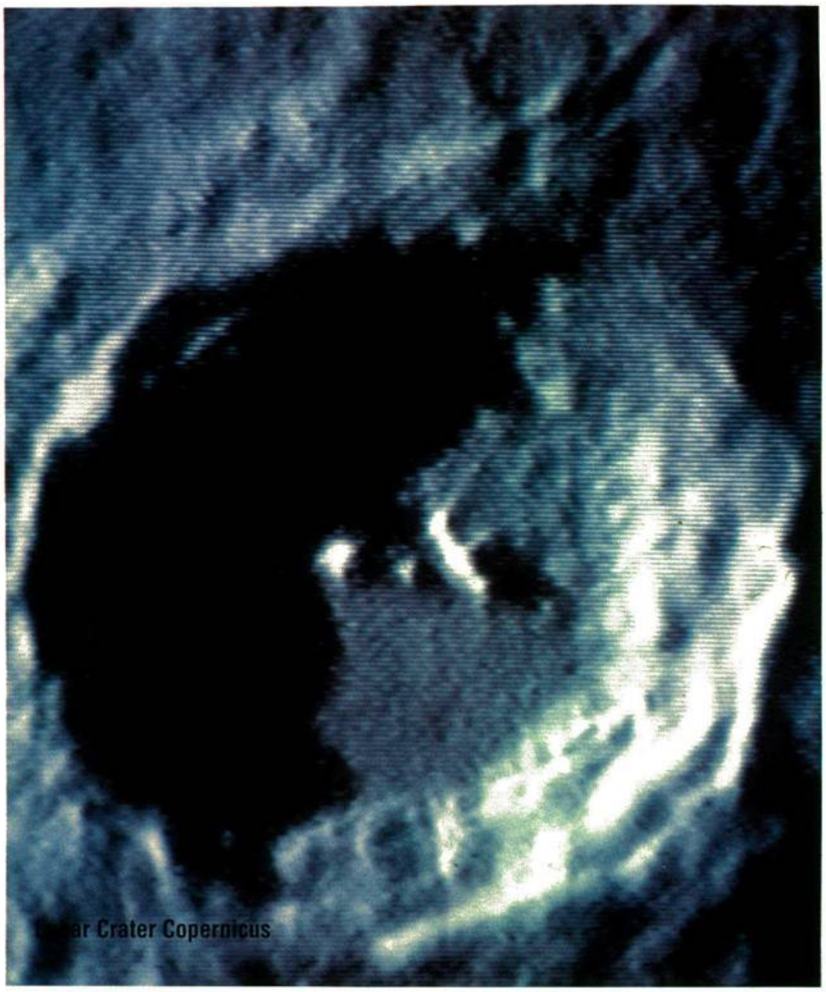
Recording Your First Astrotape

Regardless of the camcorder type you have or choose to buy, the procedure for using it is the same simple, straightforward operation. To record your first astrotape, set up your telescope as you usually do and place the camcorder on its tripod. After making sure the camcorder contains a videotape and the lens cap is off, carefully move the camcorder and its tripod so that the lens is pointing straight into the eyepiece of the scope. You will have to adjust elevation and tilt so that the camera lens is parallel to the eye lens of the eyepiece. Eyeballing this usually suffices. Next, set the camera's zoom lens to its shortest focal length. This will give you a relatively wide field that will take in all of the eyepiece view.

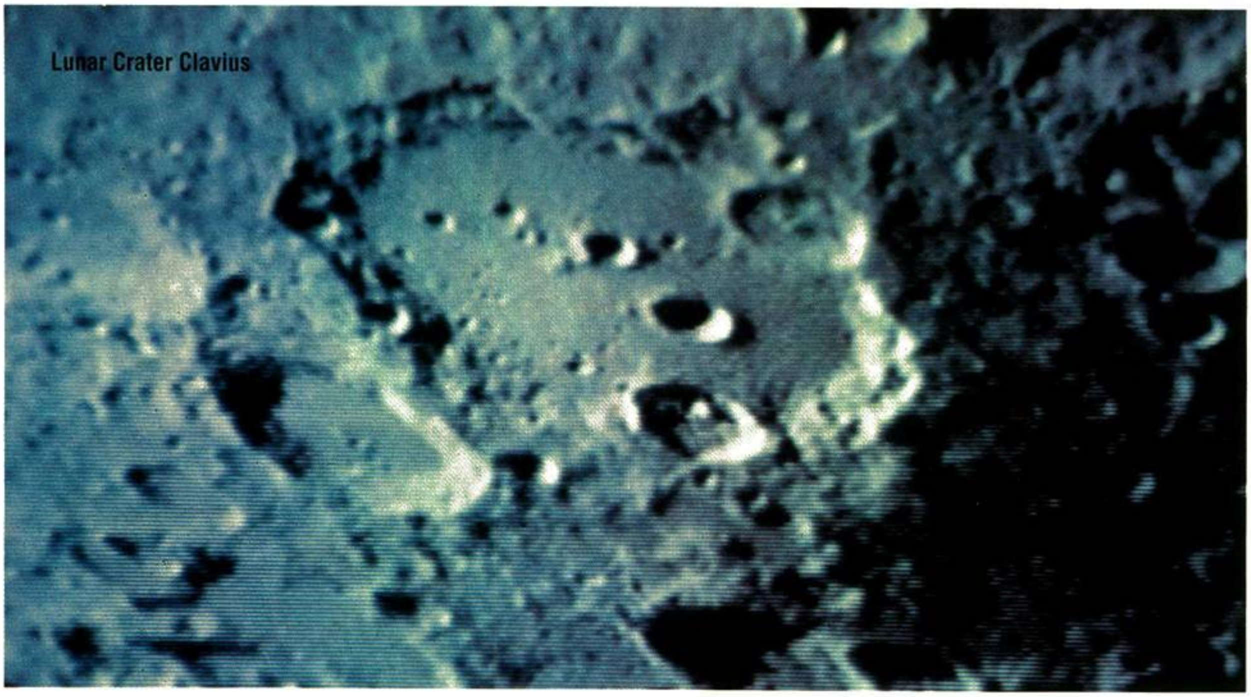
Looking through the viewfinder, move the camera around until you have the image on screen. Then move the camera and tripod to center the image on the middle of the screen. Positioning the camcorder this way is a bit tricky at first, but with a little practice you will master it. Once the image is centered on the viewfinder screen, enlarge the image by zooming to a longer focal length. As you zoom out, two things will happen. First, the circular image of the eyepiece field will seem to expand out beyond the camera's field of view. Second, you'll see that cen-

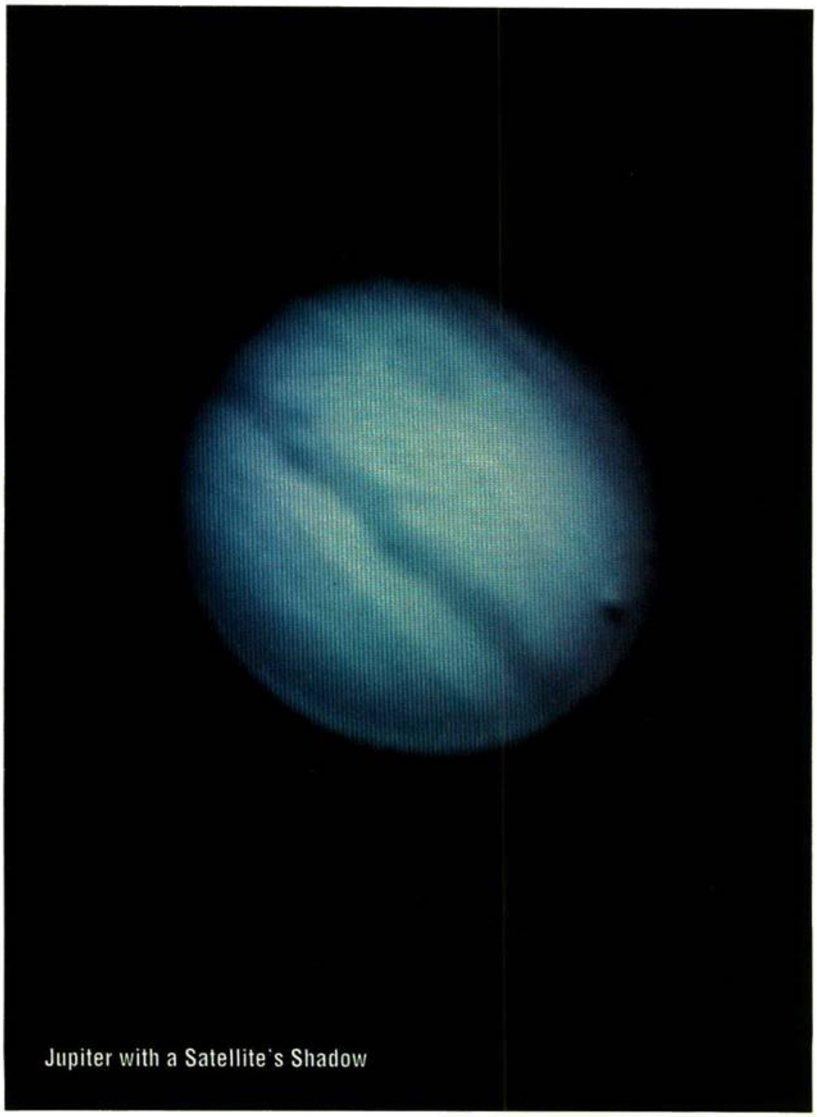


Sunspots near the Solar Limb



Lunar Crater Copernicus


Lunar Crater Clavius


Jupiter with a Satellite's Shadow

tering at longer focal lengths is more critical than at shorter focal lengths.

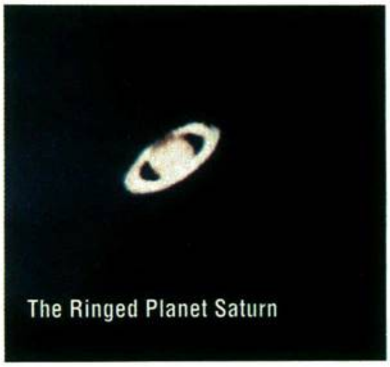
Once positioned properly, the image will eventually move outside the camcorder's field because the camcorder is not physically following the telescope. To keep the image centered, you'll have to reposition the camcorder every little while. For example, with my 8-inch SCT, I need to recenter the image about every two minutes. To make things easy, use a long focal length eyepiece. This allows a wide cone of light to exit the telescope and minimizes the amount of repositioning you'll have to do. I've found a 12mm orthoscopic eyepiece provides an excellent compromise between magnification and viewing time.

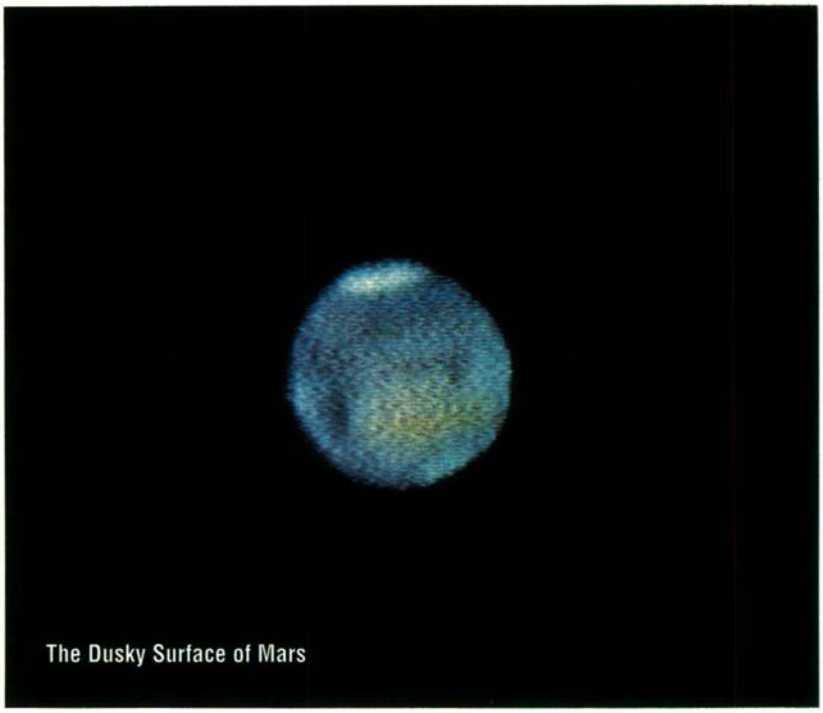
The delicate task of controlling the exposure at the camera determines how your image will appear when it's recorded on tape. If you try to enlarge the image too much, the camera will record a large, fuzzy image with muddled colors and little detail. If the image is too small it will appear saturated, nearly colorless, and without much detail. Determining the right amount of "zoom" to use when you aim the camcorder into the eyepiece depends on the object you're recording, the telescope's characteristics, and your personal preference. The best advice is simply to experiment until you make tapes that satisfy you.

No matter what camcorder you use, you'll find a range of focal lengths at which the camera performs best. Let's say you want to set

The Slender Crescent of Venus

Double Star Gamma Leonis


The Ringed Planet Saturn


The Dusky Surface of Mars

the camcorder's zoom lens to achieve maximum detail in the image. With an 8-inch telescope and a camcorder with a sensitivity of 7 lux, image size is less important than proper exposure. The easiest way that I have found to guarantee well-exposed footage is to use the viewfinder on the camera and adjust the zoom lens focal length until I see pleasing amounts of detail. Ideally, the best way to get optimum exposure is to preview the tape on the television on which you will be viewing the tape. However, if you are at a remote location, shoot a number of tapes and learn how well-exposed footage appears in the camcorder viewfinder. When you're recording tape, periodically change the focal length. This will show you the range of results you can get. Viewing those results later on will help fine-tune your eye for later expeditions under the stars.

The real beauty of video astronomy comes when the sky is cloudy and you can still view the Moon and planets on your tapes. Televisions are designed and normally adjusted to display bright pictures in brightly lit rooms. Moreover, they are designed to display brightly colored hues. Planetary images, on the other hand, are low in contrast and have subtle color hues. When you view astrovideos, you'll want to manipulate the color, contrast, hue, and fine-tuning controls on your television to bring out the most detail in your images. For example, you may wish to display the Moon in stark, high contrast, while subtle double stars or planetary detail may be best viewed with a low-contrast, colorful image.

After you've become familiar with the basic routine of astrovideography, you'll be ready to record lots of lunar, planetary, and stellar details and build a library of interesting tapes. You can then show your family that the camcorder gets used for more than Sunday outings to the beach. Who knows — maybe you'll even get the kids out under the stars! ☐

Michael Chibnik is an enthusiastic observer and astrophotographer living in Simi, California. He is a member of the Ventura County Astronomical Society.

Ten Tips for Improving Your Telescope

Buying a bigger telescope? Wait a minute! Before you spend lots of money on a new telescope, try improving the scope you already own.

by Alister Ling

The more I use my telescope, the happier I get. Buy a new telescope? Not me! Over the last few years I've stayed faithful to the same well-used telescope, but I've improved it so it now delivers sharper, brighter images. As a result I'm even more enthusiastic about observing than ever before. Some of the improvements I've made cost me only a few dollars, but, admittedly, some cost a few hundred.

To tweak up a telescope for maximum performance, here are a few simple techniques I've found to be effective. Although each improvement is small by itself, the sum of the improvements gives your old telescope a whole new life.

Clean Your Optics

Whether you're observing the festoons and white spots of Jupiter, the amazing structure of the Orion Nebula, or simply trying to detect a distant galaxy, good contrast is key to your success. Contrast is the difference in brightness between the object, or the detail of interest (the signal), and its surroundings (the noise). A down-to-earth parallel is a snowy TV picture. The solution is not a bigger set or brighter image tube but a better antenna or shielded cables to give you a cleaner, noise-free signal.

The first step towards sharp, high-contrast images is to keep your optics clean. Have you ever seen the nebulosity around the Pleiades star cluster? If so, you may have been fooled by light scattered by a layer of dust on your main optics or on your eyepiece. If the nearby Hyades appear to have nebulosity, then your optics are dirty or coated with dew. To get rid of the dust, follow the manufacturer's instructions on cleaning your telescope's optics. Be careful and be gentle; you don't want to create scratches. And while you're at it use some lens cleaning tissue to clean your eyepieces.

Dust promotes the condensation of water vapor, which in turn also creates false nebulas around stars. To retard the formation of dew keep your optics clean. On refractors and Schmidt-Cassegrains you should also use a dewcap. As a bonus this simple tube extension also shields the optics from stray light. However, if enough humidity is present, condensation will eventually occur regardless of whether or not you have a dewcap. In that case the only prevention is to rig up a gentle heating unit with nichrome wire or a series of resistors to keep the optics above the dewpoint temperature. (See "Build a Heated Dewcap for Under $10," November 1987.) Commercial heating units, such as Tuthill's "NoDu" and Orion's "Dew Zapper," are available. As an alternative a hair dryer set on "low" and blowing gently across the front lens will work well, though it interrupts one's observing.

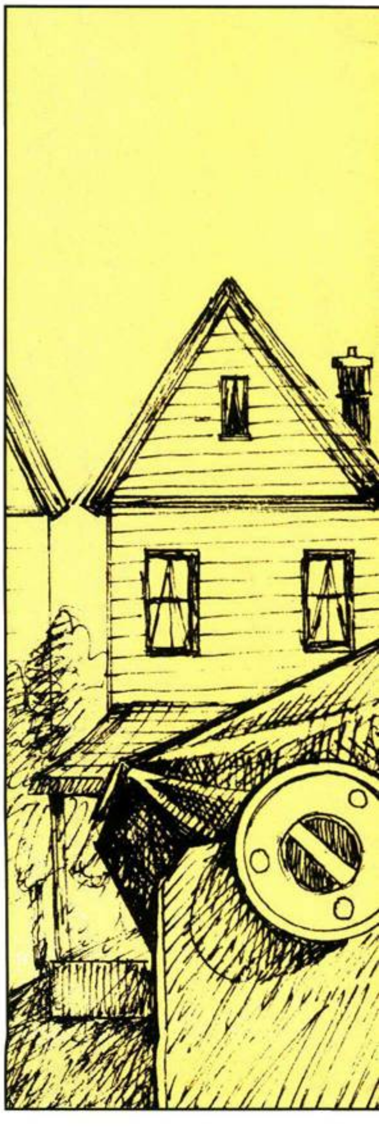
If you live in a particularly moist climate you may also need to use nichrome wire or resistors to heat the secondary mirror of your Newtonian. Purists may complain that the heat creates tube currents, but I prefer observing with tube currents to not observing at all.

Collimate Your Optics

The thought of collimating optics seems to strike fear into the hearts of many telescope owners, but it shouldn't. Once you become familiar with the procedure it takes about ten minutes to do. The results actually make a big difference.

At its worst, poor collimation can make a mirror with a surface accuracy of 1/20-wave perform like a 1-wave mirror. Star images, indeed all images, will be indistinct blobs. After collimation planetary details like the Red Spot and mottled belts on Jupiter snap into focus. Dust lanes and nebular complexes in galaxies practically pop into view.

Although Newtonians are most easily knocked out of alignment, Schmidt-Cassegrains can be bumped too. Consult your owner's manual for the proper procedure for getting the optics back in line. Refractors are diffi-



cult to collimate. Luckily they rarely need adjustment, but if they do it's best to leave the task to an expert or the manufacturer.

Baffle Your Newtonian

No, this doesn't mean confuse your telescope. Baffling refers to cutting out stray light entering the field. Refractors and Schmidt-Cassegrain telescopes with dewcaps are usually well baffled, but Newtonian telescopes can be flooded with unwanted light, from light pollution to the Milky Way itself. The result is a brighter-than-necessary sky and washed out deep-sky objects. Large Dobsonians with open-tube frameworks are particularly susceptible, since the optics are exposed to the open air.

An inexpensive solution for these open-tube telescopes is to purchase a couple of yards of black cloth and create a shroud to wrap around the tube framework, joining the ends with a big zipper or Velcro strips. As a further preventative measure Newtonian telescopes should be equipped with a tube extending 12 to 24 inches beyond the position of the secondary mirror, shielding it from unwanted light. The extension tube can be a removable dewcaplike device.

The inner surface of Newtonian tube walls, especially the section opposite the focuser, should also be covered with a flat black material like velveteen. Black corduroy, installed so the ridges run perpendicular to the light path, can also act as a very effective light baffle.

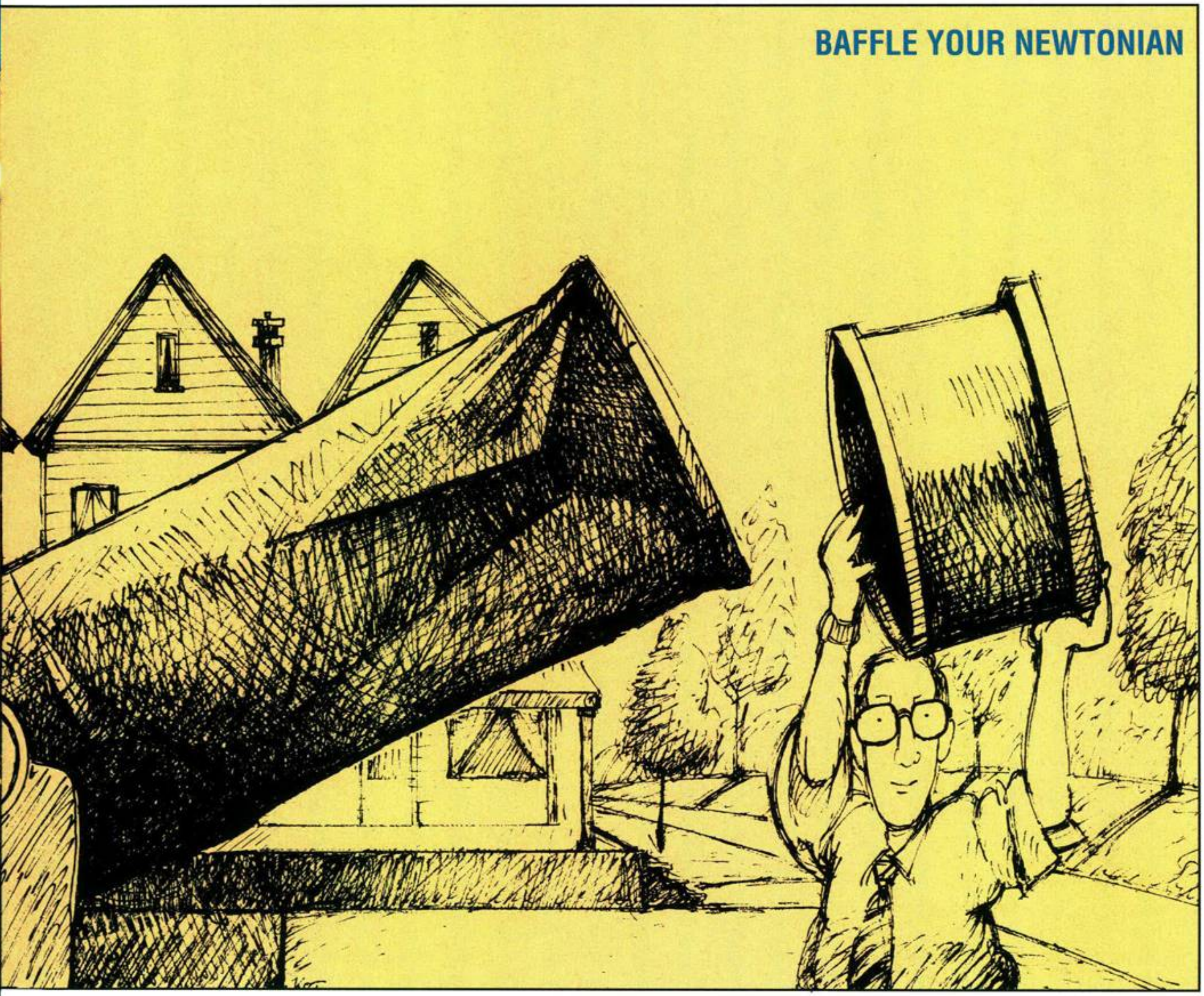
Light can also leak in from the space surrounding the mirror and focusing mounts, particularly in winter when there is snow on the ground. A simple cardboard ring at the bottom of the tube will block ground reflections while allowing the air to flow freely around the mirror.

The improvement that these contrast-boosting measures make can be dramatic. Dwarf galaxies, face-on spirals, dark nebulae, supernova remnants, and other notoriously low-contrast objects emerge from the background sky.

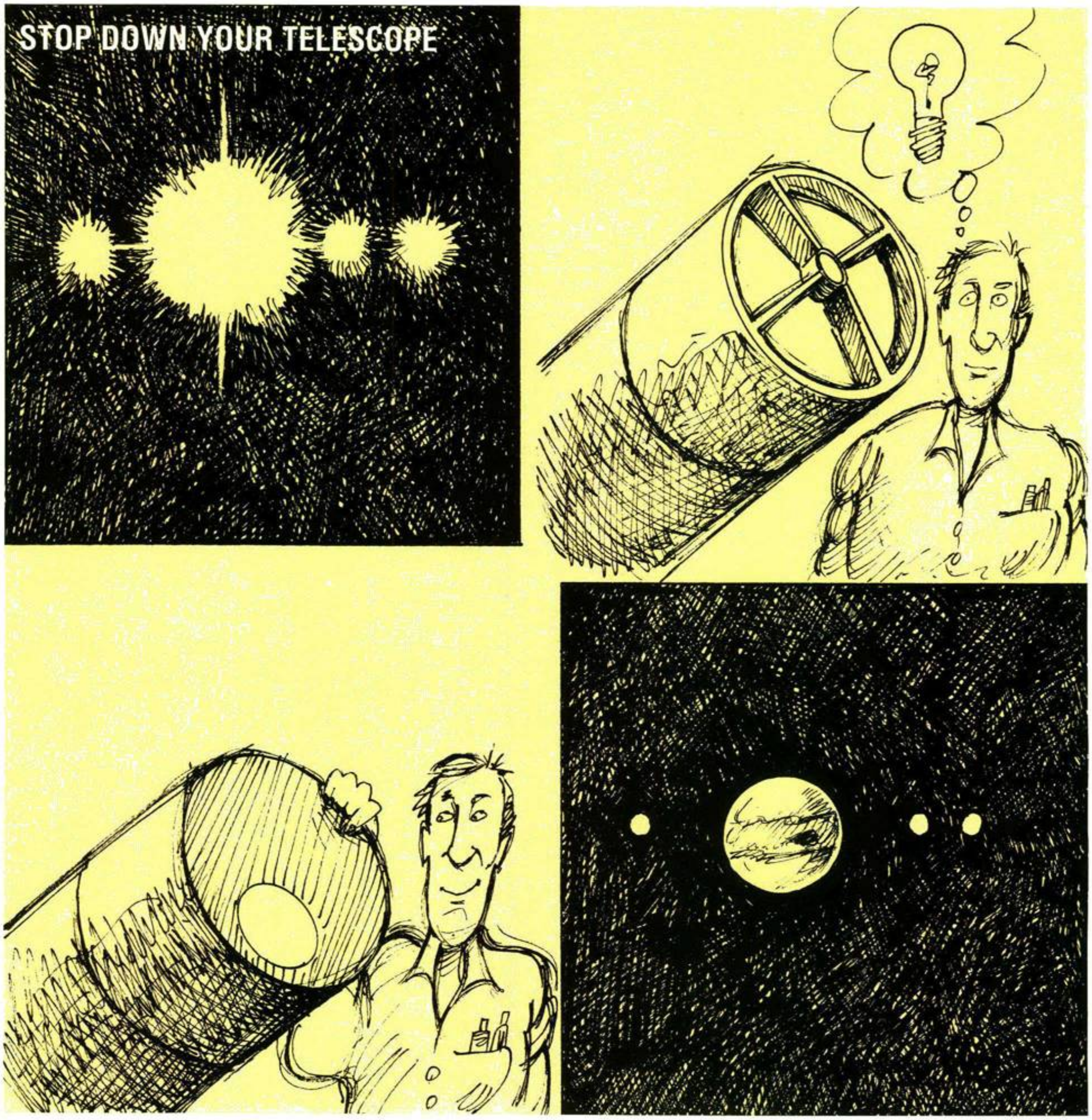
Keep Yourself in the Dark

Complete dark adaptation is critical for seeing faint deep-sky detail. Most observers never reach proper dark adaptation because they use flashlights that are too bright. Studies have shown that even red light when sufficiently bright impairs night vision.

To further increase my visual sensitivity I drape a dark cloth hood over my head to shield out interfering street lights or reflections from the telescope tube. The hood may look strange but I find that I can observe diffuse ob-



BAFFLE YOUR NEWTONIAN



jects almost two magnitudes fainter than I can without the hood. Who needs a bigger telescope? Once your eyes are at "maximum gain" you can use much higher powers, a proven technique for seeing threshold detail in galaxies and nebulae.

Since the hood traps the moisture from your face, you may need to buy or rig up a little heater for your eyepiece to prevent dew from forming on the lens. A simpler solution is to step away periodically to let the pocket of humid air disperse.

Stop Down Your Scope

Yes, you can turn your Dobsonian light bucket into a planetary telescope. All you need to do is make a cardboard off-axis mask. A 16-inch f/4 telescope can be converted into an unobstructed 5.5-inch f/11.6. Because the diagonal and spider vanes are not blocking the light path, they will not create diffraction spikes. The cardboard stop reduces the intensity of the Moon or bright planets to a bearable level. Also, the smaller aperture is less affected by turbulent cells of atmosphere that create poor seeing. The overall result, provided your mirrors are of reasonable quality, will be sharper images.

Stop the Shakes

I used to have problems focusing at high power because the telescope vibrated too much. There's nothing more annoying than shaky images that prevent you from finding the point of sharpest focus. A motorized focus unit did the trick for me. If you have a tripod-mounted telescope like a Schmidt-Cassegrain a set of footpads such as "Shake-Enders" will cut vibration in half on most telescopes. (See "ASTRONOMY Tests the Epoch Instruments Shake-Enders," February 1990.)

Filter Out Bad Light

Although they can cost $75 to $125, nebular filters can make a big difference. They boost the contrast between a deep-sky object and the background sky by blocking both manmade lights and natural airglow. I have yet to see an observer who was not amazed by the difference the right nebular filter makes.

The right filter depends on your observing interests. If you're seeking galaxies and reflection nebulae, a gentle broadband filter like Lumicon's Deep-Sky or Orion's SkyGlow Broadband models are best. For emission nebulae like the Lagoon or planetary nebulae like the Owl, a narrowband "high-contrast" filter like Lumicon's UHC or Orion's UltraBlock are preferred. The majority of filters sold by other manufacturers also fall into this category. Planetary nebulae also benefit from "line" filters such as Lumicon's O III type, but because they reject all but a select range of wavelengths, the O III filters can darken the field so much that it is difficult to see anything through them. This is often the case when they are used at the high powers produced by slow f/10 to f/15 telescopes.

If you own a nebular filter but find you have a problem looking through it, try the dark cloth hood. Without it stray light can reflect off your eyeball, into the eyepiece, and bounce off the silvery back of the filter, clouding the view. Combined with a dark hood a nebular filter can bring out the very faintest tendrils of nebulae like the Crescent or the Veil, especially when used in a dark sky.

New Eyepieces

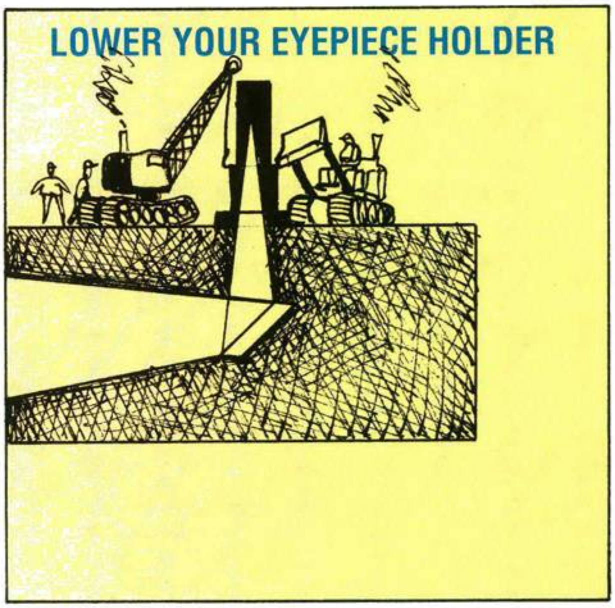
Okay, now we're talking big money. These days top-of-the-line eyepieces can cost from $100 to $300 each, but the new views they provide can be wonderful. For example, with a long focal length eyepiece you can turn your telescope into a rich field wide-angle scope. A 55mm eyepiece on a 2,000mm focal length f/10 Schmidt-Cassegrain will give you a 5.5 mm exit pupil and a field nearly 1.4° wide — about three Full Moon diameters. You may need to purchase a 2-inch star diagonal, but in a dark sky the wide fields are amazing to behold. Just scan along the rich summer Milky Way and you'll see what I mean.

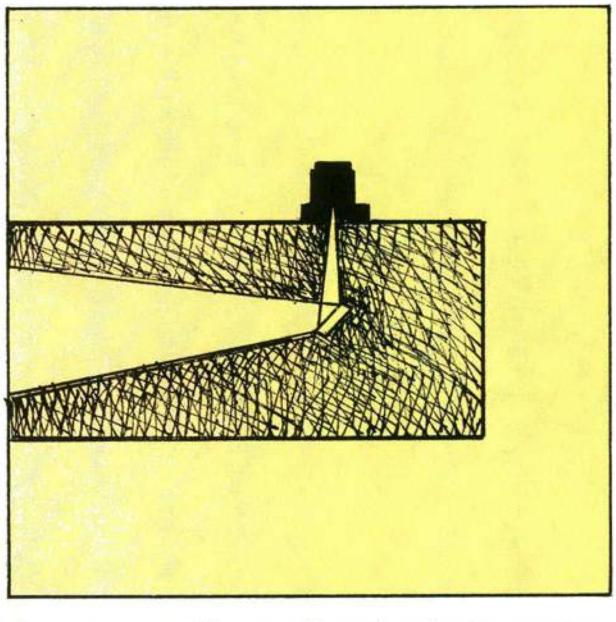
If you want to combine moderate to high power and retain a wide field with pinpoint stars to the edge, the 7- or 8-element TeleVue "Nagler" and Meade "Ultra-Wide" eyepieces are the only way to go. These premium eyepieces are designed to handle the steep light cones from today's f/4 to f/5 Newtonian telescopes. They are vastly superior to the old Erfle wide-angle designs that are plagued with fuzzy star images at the edge of the field.

If planetary observing with a clock-driven telescope is your forte, consider a set of top-quality Plössl eyepieces. They give sharp contrasty images in the center of the field with minimal ghost images. For planetary observing, seeing fine details is more important than a wide field.

Lower Your Profile

In reflecting telescopes the secondary diagonal mirror diffracts light and diminishes contrast. For Newtonian telescopes a low-profile focuser, one that sits close to the tube, is one way around this. To take advantage of this trick you first move the diagonal mirror outward from the main mirror where it intercepts a smaller light cone. You can then switch to a smaller diagonal, which results in less diffraction. This in turn concentrates more light into the smallest area possible. Since the focal point will now fall closer to the tube, you need the low-profile focuser if your eyepieces are to reach focus.





However, of all the improvements I'm recommending that cost money, this one will produce the least noticeable return on your investment. Make it the last on your tune-up list. If you do change your diagonal mirror, be sure to get one with enhanced aluminum coatings for maximum reflectivity. Compared to standard aluminum coatings the enhanced variety can reflect 8 to 10 percent more light, the equivalent of perhaps another half-inch of aperture.

Finders of All Types

If you're like most amateurs, finding deep-sky objects is a chore. Inverted or mirror-image finder scope fields, dim finder views, crawling on hands and knees to sight along tubes — these can all be frustrating and inconvenient. By far the most elegant solution to pointing problems that I've found is the ingenious Telrad finder. It simply projects faint red bull's eye onto the sky when you look through it. You can't miss. For the budget-minded a gunsight arrangement with a bolt and washer spaced along the tube will work almost as well.

KEEP YOURSELF IN THE DARK

OBSERVE WITH A GROUP

Of course, to help you find your way around the sky you can also buy bigger finder scopes, better star charts, or even go electronic with digital setting circles and computers like Meade's CAT and Celestron's Advanced AstroMaster. But a low-tech method many people ignore is getting involved with an observing group of two to five people. Friends make the best finder scopes. Each person finds something unique and shares it with others. Group members challenge each other to see interesting objects. Once you've sighted or seen an object in your friend's 12-inch scope, you'll often be surprised how easy it is to see in your 8-inch.

The result of the team approach is that you see more and have a lot of fun in the process. You'll also get out more often. My observing buddy Jerry Spevak and I usually manage to convince each other to go out to the observatory even when conditions aren't optimal. If the sky stays clear we feel great. And if the risk didn't work out, we still get a pleasant evening talking and planning future sessions.

Why should you make the effort to squeeze the last bit of performance out of your modest telescope? Why not simply buy a larger telescope? Even if you can afford them, large telescopes aren't always the answer. For one thing they aren't as portable and are far more difficult to set up than smaller scopes. Chances are you'll use a good small scope more often than a big heavy telescope, no matter how good the optics are. After all, the best tip for seeing more through a telescope is to use it as often as you can. ☐

Alister Ling is a professional meteorologist for Environment Canada and an avid deep-sky observer. He writes a regular column, Small Scope Showcase, in Deep Sky magazine.

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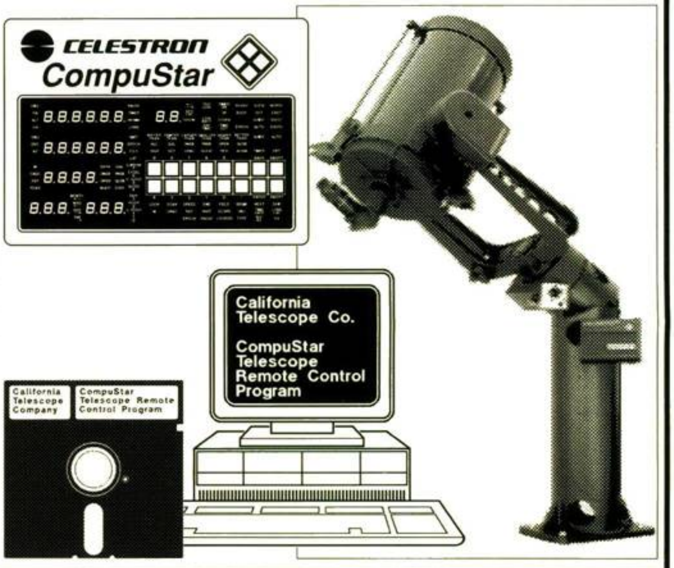
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The Galaxies of Cetus

Cetus the Whale is chock full of pretty, challenging galaxies for small telescopes.

by David Higgins

Few constellations offer a window into the deep like the one in Cetus the Whale. Although this constellation appears rather empty when viewed with the eye alone, with a telescope Cetus comes alive with deep-sky wonders. By looking toward Cetus you are peering through a window that extends beyond our galaxy that reveals the realm of distant galaxies beyond.

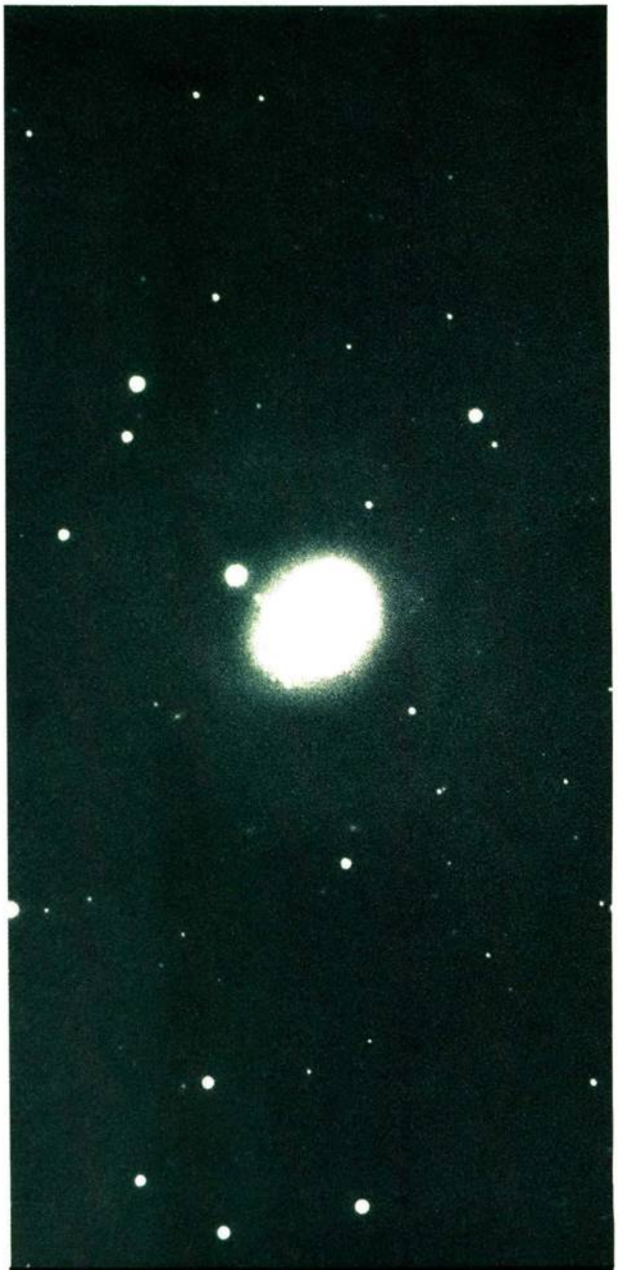
Cetus covers much of the rather empty-looking autumn sky. Although it is not one of the brighter constellations, Cetus covers a total of 1,231 square degrees of sky and offers ample room for galaxies ranging from the extremely faint and difficult to the very bright and prominent. Some of the fainter galaxies require a large telescope, but there are enough galaxies within reach of the average amateur telescope to provide you with plenty of interesting deep-sky objects to observe on those clear, crisp fall evenings.

By far the brightest and largest galaxy in Cetus is **M77** (NGC 1068), the only Messier object contained within the whale's borders. This should give you some idea as to the apparent brightness of the other galaxies in this area of sky. Lying at a distance of 60 million light-years and glowing at magnitude 8.8, M77 is a member of an extraordinary class of objects known as Seyfert galaxies. These galaxies exhibit a distinctive emission line spectrum and have an active, highly energetic, starlike nucleus. Seyfert galaxies are also moderately strong radio sources.

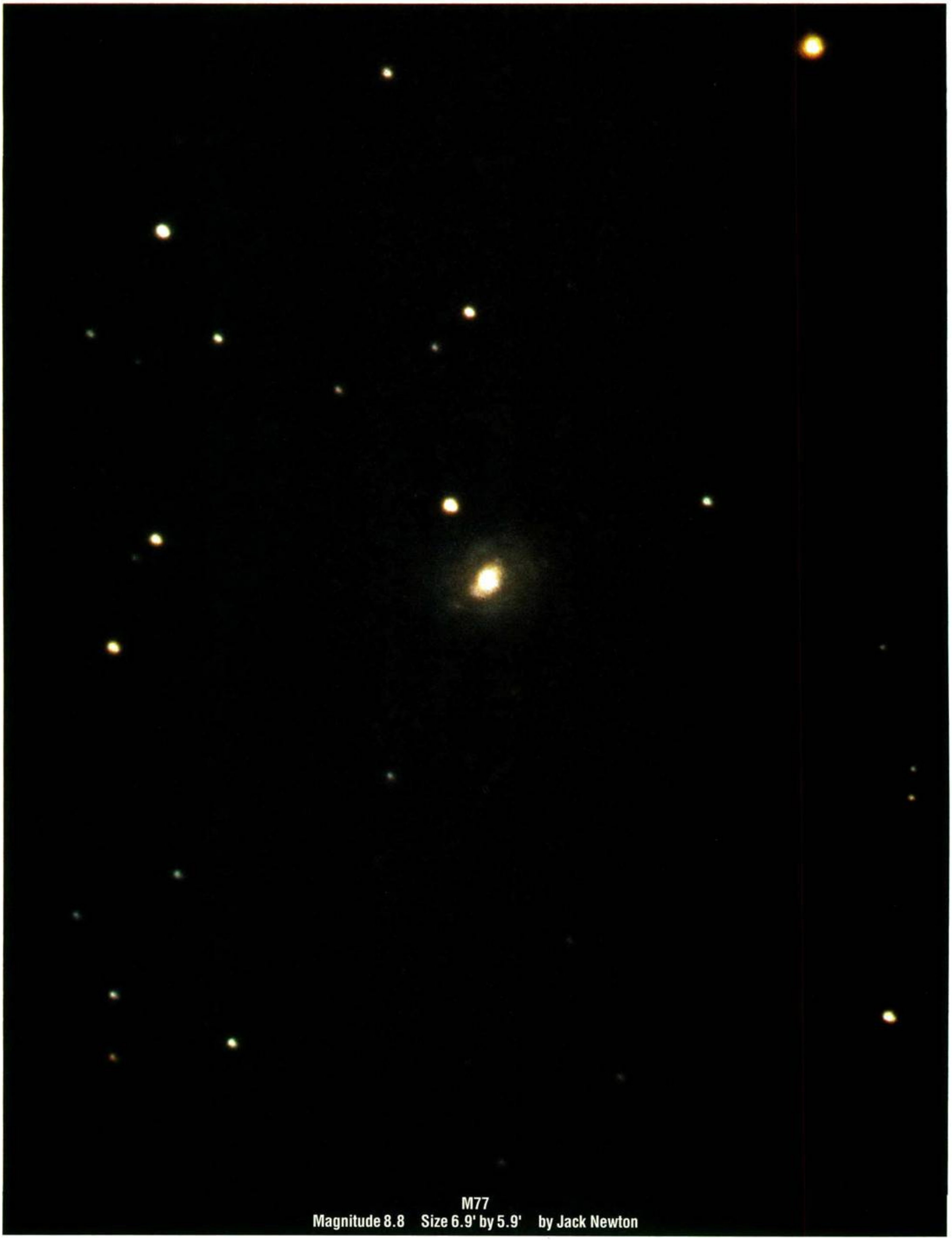
M77 is the brightest of several galaxies clustered around the bright star Delta Ceti. It is a simple matter to find M77. Look about 1° southeast of Delta Ceti and you will find a softly glowing cloud with a very bright and condensed core. Measuring 6.9' by 5.9', M77 is a face-on Sb spiral galaxy. In general, face-on spirals are not exceptionally distinct compared with edge-on systems, but M77 is an exception.

In small telescopes M77 appears bright and has an intensely prominent nucleus. A noticeable field star that rivals the brightness of M77's core lies on the galaxy's southeast edge. Try different magnifications as you observe M77. Telescopes in the 8-inch range present a very different view. The nucleus appears much more stellar and the haze surrounding the nucleus is brighter and gradually fades outward. Mottling is visible, especially around the galaxy's southern edge. Some hint of spiral structure may be visible on good nights.

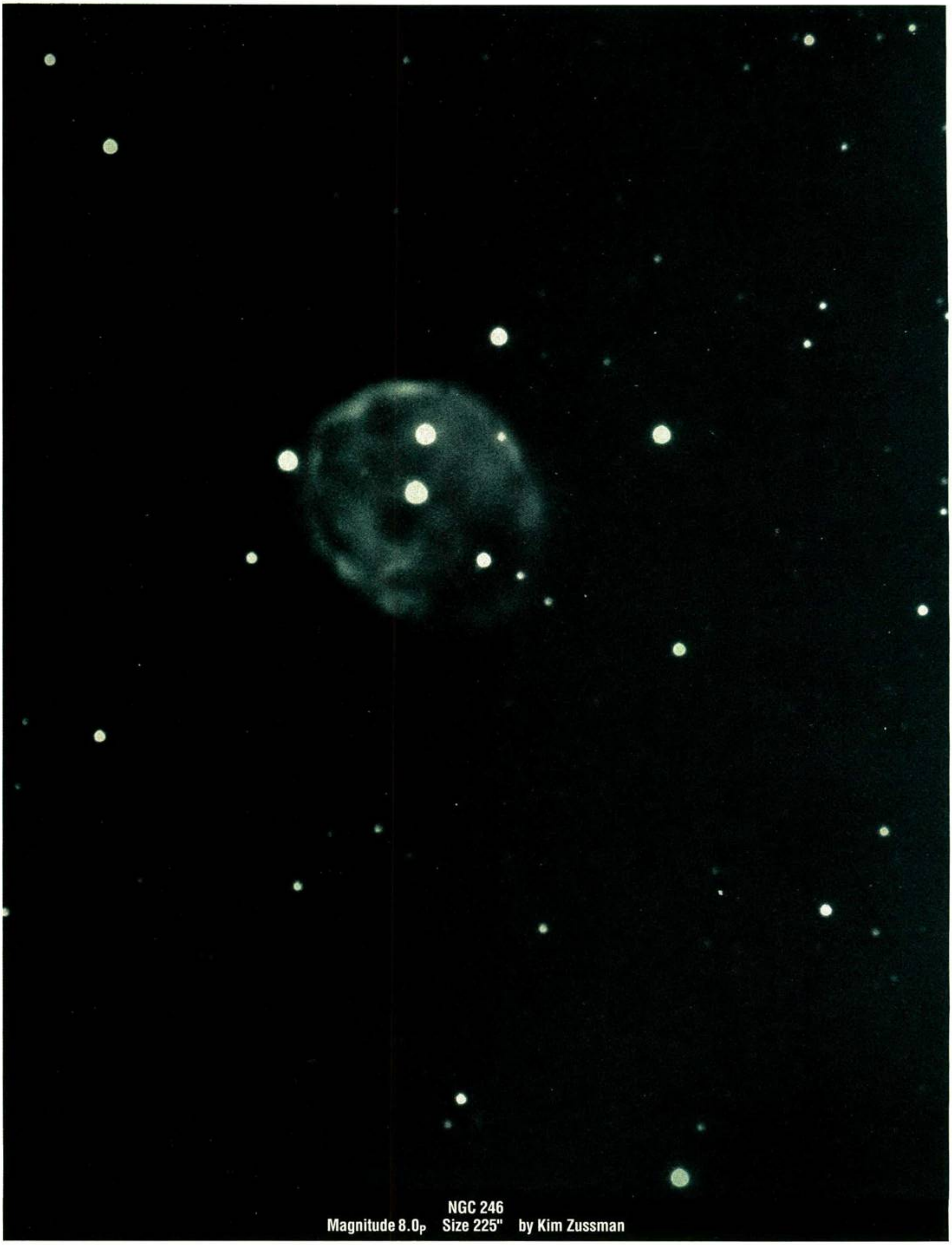
In 12-inch to 14-inch telescopes the view of M77's nucleus is improved. The nucleus is slightly more stellar



M77
Magnitude 8.8 Size 6.9' by 5.9' by Kim Zussman



M77
Magnitude 8.8 Size 6.9' by 5.9' by Jack Newton



NGC 246
Magnitude 8.0$_p$ Size 225"   by Kim Zussman

NGC 246 and NGC 255
Mags. 8.0$_p$ and 11.8 Sizes 225" and 3.1' by 2.8' by Mace Hooley

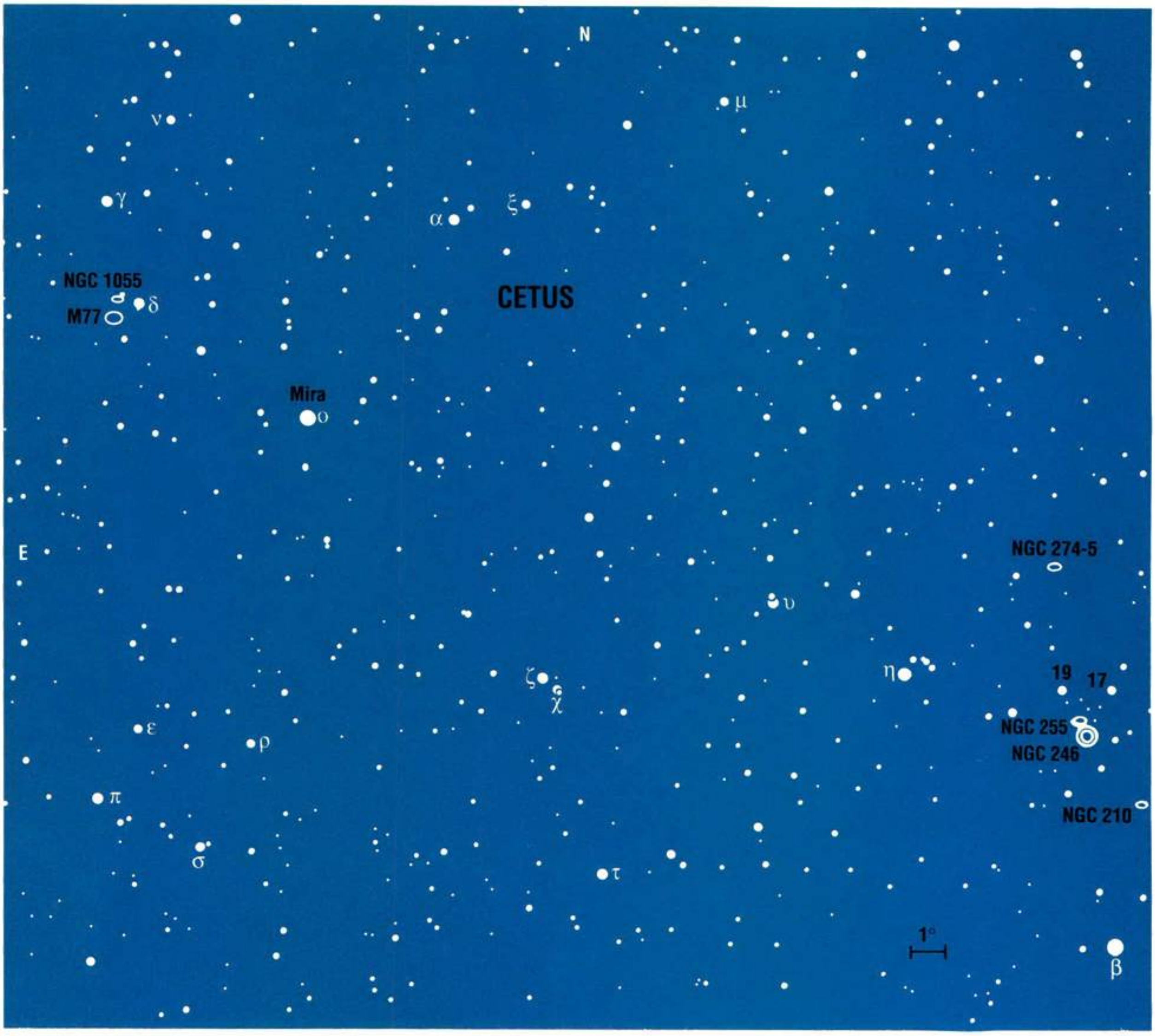
and the surrounding haze more intense. The galaxy's southern edge is much more mottled and pronounced, and on nights of good seeing the spiral structure becomes much easier to see. If you catch a really good night you can glimpse individual knots of nebulosity on the southern edge with averted vision.

Telescopes larger than 16 inches in aperture show an amazing amount of detail in M77. Spiral structure around the galaxy's southern edge is easily seen. The galaxy's nucleus appears absolutely starlike. The haze that extends outward from the nucleus is very bright and well defined.

Observing galaxies requires patience, skill, and some time-tested techniques. Dark adaptation is something that all observers, beginners and old hands, know is critically important. Don't be reluctant to try high magnifications. Each jump in magnification will provide you with a different and sometimes surprising view. Using high magnifications not only yields larger images but also greater contrast between the galaxy and surrounding sky. Averted vision also helps bring out hidden details that might not be apparent with direct vision.

About 30' northeast of M77, within the same low-power eyepiece field, is the faint edge-on spiral **NGC 1055**. This galaxy is elongated east-west and shows little structure or detail, except in large scopes. Glowing at magnitude 10.6 and measuring 7.5' by 3', NGC 1055 is visible in 6-inch scopes as a faint haze surrounding a bright, elongated nucleus. In large scopes averted vision reveals a small amount of mottling with a dark lane bisecting the nucleus.

M77 and NGC 1055
Mags. 8.8 and 10.6 Sizes 6.9' by 5.9' and 7.6' by 3.0' by Jeffrey L. Jones



Lying alongside the whale's head are several interesting galaxies awaiting inspection. One that is fairly bright but a little difficult to find is **NGC 210**. Located a little over 1° southwest of 18 Ceti, NGC 210 glows at magnitude 10.9, measures 5.4' by 3.7', and is an Sb-type spiral. In small scopes it is a large, faint oval of light with a nucleus a little brighter than the surrounding haze. In larger scopes the nucleus appears much brighter and extends north-south. Don't be afraid to use high magnifications on this galaxy.

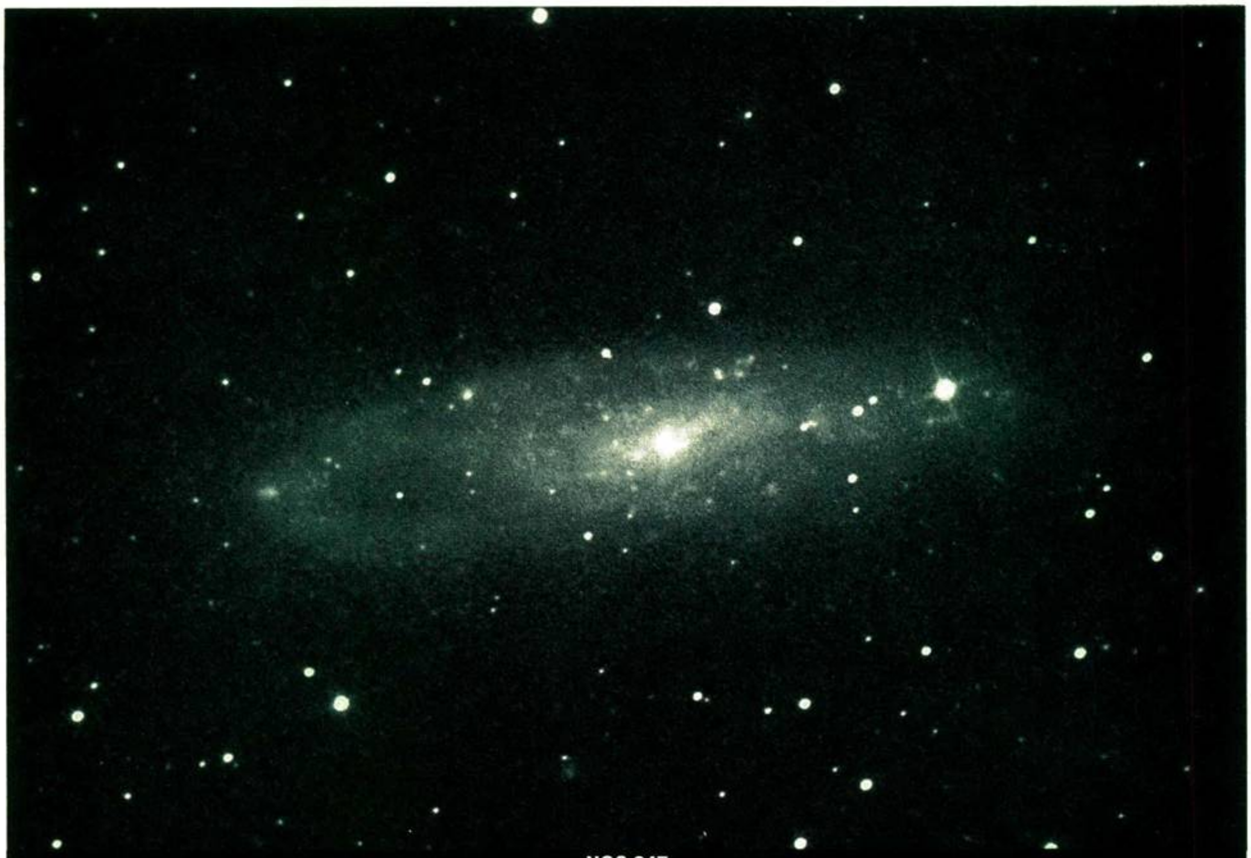
Like M77, NGC 210 has a fainter neighbor that can be seen in the same low-power field. Lying about 20' southwest of NGC 210, **NGC 178** is a faint oval haze with no detail in small scopes. Ten-inch scopes show a brighter nucleus that extends a little north and south. The faint haze that surrounds the nucleus fades gradually outward.

Not too far northeast of NGC 210 lies another faint spiral. **NGC 255** is a small, face-on Sb spiral. Forming a lopsided triangle with 19 and 17 Ceti, NGC 255 lies about 1° south of these 5th-magnitude stars. Small scopes show a small oval haze with no sign of any nuclear brightening. Telescopes greater than 10 inches in aperture show the galaxy's nucleus as a bright ringlike

Galaxies in Cetus

Object	R.A. (2000.0)	Dec.	Mag.	Size
NGC 175	0h37.4m	-19°56'	12.1	2.6' by 2.4'
NGC 178	0h39.1m	-14°10'	12.6	2.0' by 1.2'
NGC 210	0h40.6m	-13°52'	10.8	5.4' by 3.7'
NGC 246	0h47.0m	-11°53'	8.0_P	225"
NGC 247	0h47.1m	-20°46'	8.8	20.0' by 7.4'
NGC 255	0h47.8m	-11°28'	11.8	3.1' by 2.8'
NGC 273	0h50.8m	-06°53'	13:P	2.6' by 0.9'
NGC 274	0h51.0m	-07°03'	12.9_B	1.7' by 1.6'
NGC 1055	2h41.8m	+00°26'	10.6	7.5' by 3.0'
M77	2h42.7m	-00°01'	8.8	6.9' by 5.9'

Object: Designation in Messier or NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude, B magnitude (subscript B), or photographic magnitude (subscript P). **Size:** Diameter in arcminutes or arcseconds.



NGC 247
Magnitude 8.9 Size 20.0' by 7.4' by Martin C. Germano

structure, surrounded by a faint glow.

NGC 255 shares the same low-power eyepiece field with **NGC 246**, a large planetary nebula that glows at photographic magnitude 8.0. Measuring 225" across, NGC 246 is easily seen with small telescopes when it is near the meridian. Low magnifications yield the best views; nebula filters like the UHC help greatly by boosting contrast. Several dark areas are visible in the nebula. The object's central star and several others inside the nebulosity are easily seen.

About 4° north of 19 Ceti you will find a little trio of galaxies with an unusual range of sizes and brightnesses. **NGC 274** is the largest of the three, measuring 1.7' by 1.6' and glowing at blue magnitude 12.9. Almost on top of NGC 274 and a little to the east is **NGC 275**, which glows at magnitude 12.5 and measures 1.5' by 1.2'.

The third member of the group is **NGC 273**, which lies just to the north. Measuring 2.6' by 0.9' and glowing at 13th magnitude, NGC 273 is the faintest of the three. Regardless of what size telescope you are using, there is little to be seen in this galaxy.

NGC 247 lies about 3° south of Beta Ceti, glows at magnitude 8.8, and measures 20' by 7.4'. NGC 247 is a very large galaxy. Its light is spread out over such a large area that its surface brightness is rather low. Small scopes show a faint haze without any central brightening and a 9th-magnitude star positioned in the southern portion of the galaxy.

Scopes in the 12.5-inch range show some hint of structure around NGC 247's edges. The northern portion is somewhat larger and more easily seen. The nucleus becomes visible with a gradual brightening outward. In large scopes the galaxy's nucleus is much larger and more extended. In a 17.5-inch scope the entire galaxy takes on a mottled appearance, with some individual knots of nebulosity taking shape around the edges.

Northwest of NGC 247 you will find a small, faint SBb spiral that requires some perseverance to find. **NGC 175** glows at magnitude 12.1 and measures 2.6' by 2.4'. This face-on barred spiral is not bright in small scopes, but it is worth finding. The simplest way to find NGC 175 is to draw an imaginary line between Beta Ceti and NGC 247. Halfway between the two extend a line westward about 2°. Small scopes will show a fairly large but faint haze with no apparent nucleus. Larger scopes will show a brighter middle with a hint of elongation north and south. The halo surrounding the nucleus gradually fades outward.

Keep in mind that the galaxies you are observing are millions of light-years away. In addition to their great distance, each one has its own complement of gas, dust, and stars. Spend some time with these far-away island universes. You will not only develop some highly useful skills, you will also enjoy peering outside of our galaxy into the great spaces beyond. ☐

David Higgins is the central coordinator of the National Deep Sky Observers Society and a contributing editor of Deep Sky magazine.

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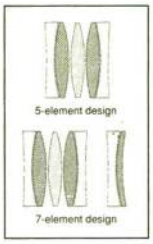

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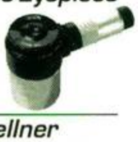

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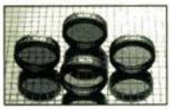

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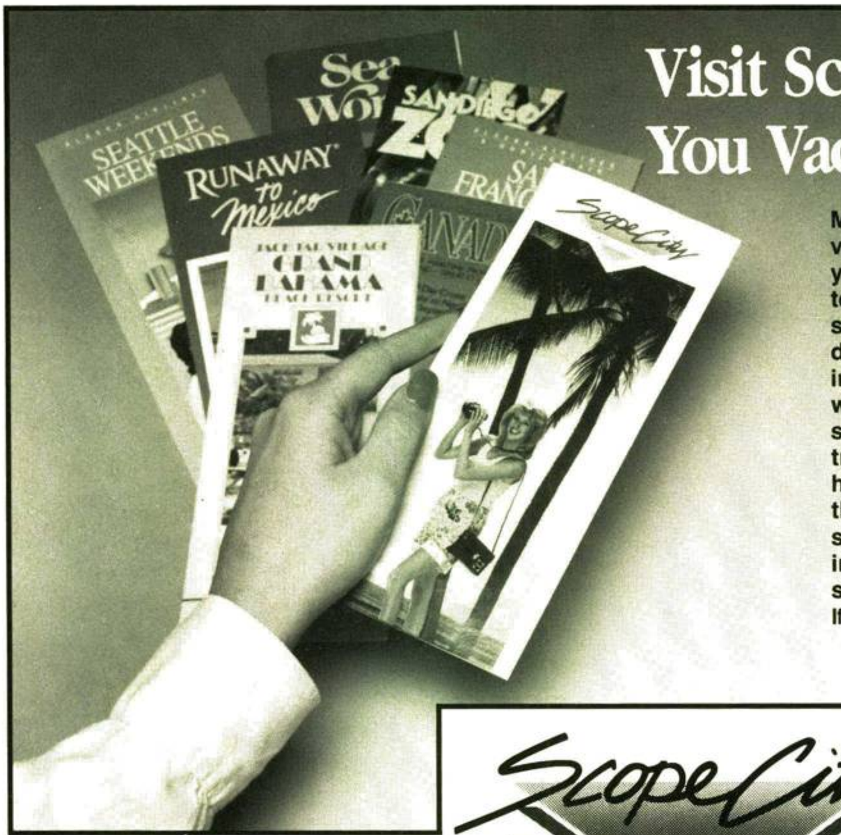

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CATCH A FLYING HUBBLE

"We were determined to see the *Hubble Space Telescope* even though we couldn't attend the launch." With these words, amateur astronomers Wayne Wooten and Merry Edenton-Wooten set out on a campaign to spot *Hubble* as it passed over their home in Pensacola, Florida, after its launch in April.

"After finding out from NASA when *Hubble* would be visible over Florida, we got up early in the morning and kept watch like a sentinel," said Edenton-Wooten. She explained, "We were used to rising early because of repeated recent attempts at spotting Comet Austin, and were bright and alert when we made our first sighting on the morning of April 28.

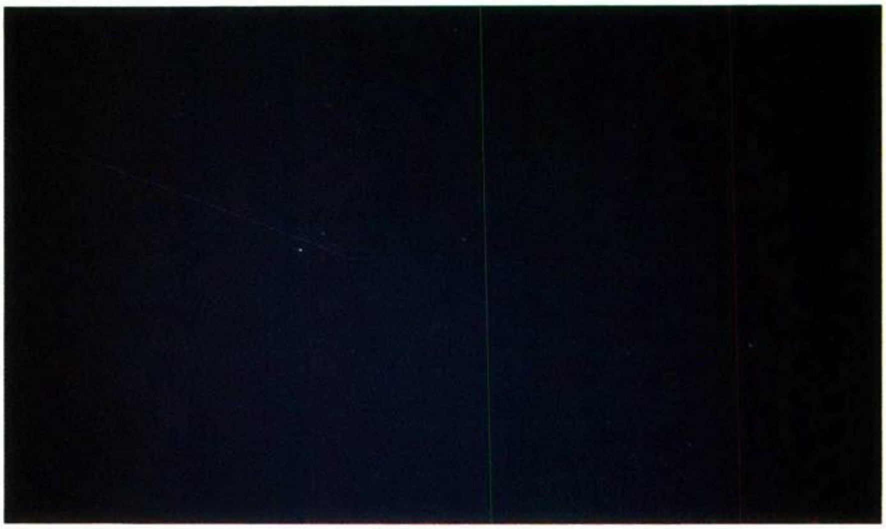
"Outside we were greeted by spotty cloud cover," said Edenton-Wooten, "but we were hoping to spot *Hubble* through breaks in the clouds. At 4:53 a.m. I became the first to see *Hubble* and shouted my surprise so that Wayne and the kids instantly spotted it too. Wayne grabbed the camera and positioned the tripod for a few hurried shots that showed *Hubble* followed by the shuttle *Discovery*. The two objects were about 60° above the horizon and some 7° apart.

"The two objects were bright and easily visible," Edenton-Wooten continued excitedly. "*Discovery* was about as bright as Saturn, and *Hubble* appeared to be as bright as the shuttle but faded slightly as the morning Sun left the solar panels.

"On the following morning, Wayne conducted a public comet watch for viewers of Austin, held at the scenic overlook at Escambia Bay. I stayed home and readied myself for the appearance of *Hubble*, preparing to take more photos and enjoy the brief view of the telescope as it made its passage overhead.

"Unfortunately the sky was predominantly cloudy when I ventured outside, but by 5:00 a.m. several breaks in the clouds appeared. *Hubble* and *Discovery* were again easily visible, this time appearing about 20° apart with an elevation of approximately 70°. The following day we were fortunate enough to capture a photo showing sunlight glinting off *Hubble*'s solar panels. What a thrill it was to see this monumental scientific instrument during its first few days in space!"

SUNLIGHT GLINTS OFF *HUBBLE* as the just-released space telescope passes over Pensacola, Florida. Photo by Merry Edenton-Wooten.



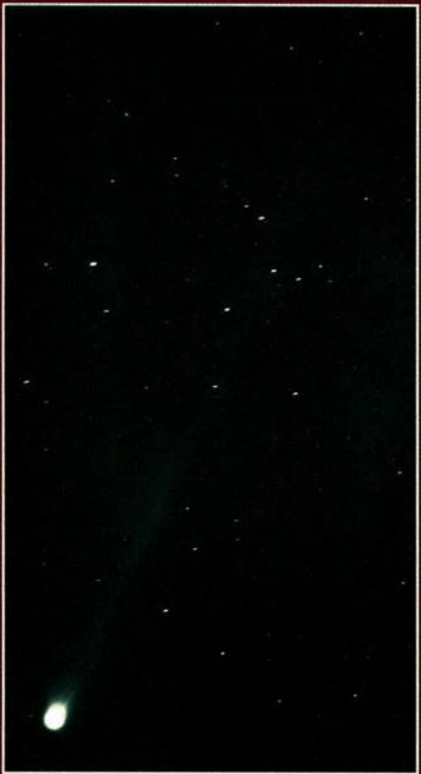
***HUBBLE* STREAKS PAST ALTAIR** in the early dawn of April 29, 1990. Photo by Merry Edenton-Wooten.

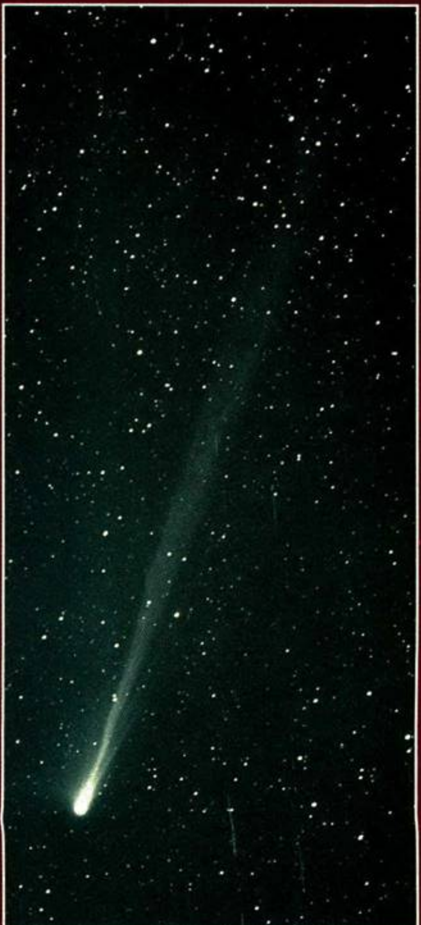
CURTAINRISE ON COMET AUSTIN

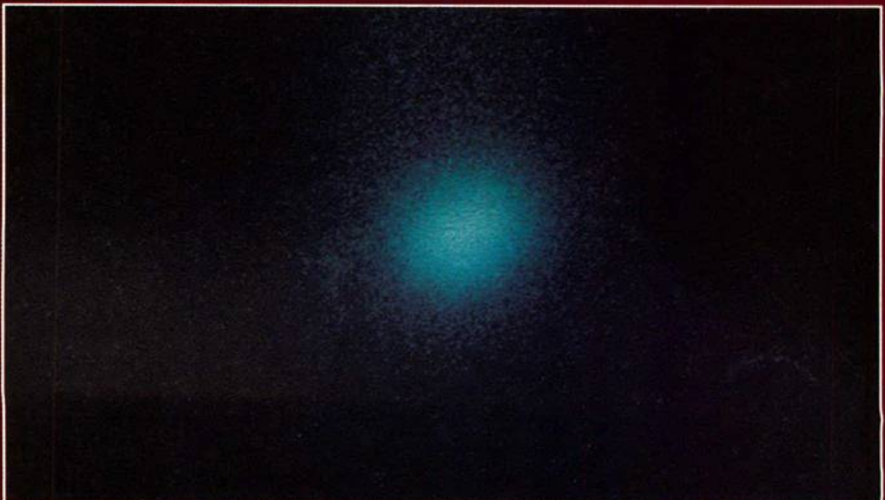
Last April long-awaited Comet Austin ($1989c_1$) finally slipped out of morning twilight and into the morning sky, where it was observed by thousands of amateur astronomers. Despite the comet's dim performance relative to early predictions, by late April Austin reached magnitude 4.5 and developed a faint tail that stretched nearly 10°. This made it a bright, attractive sight in binoculars and telescopes, as evidenced by this selection of photos.

Andreas Gada's gritty, surrealistic photo of the comet passing near the Andromeda Galaxy wins this month's $100 "Best Astrophoto" award (opposite page). Gada used a 75mm f/4.5 lens, TMAX P3200 film pushed to 25,000 ISO, and a 5-minute exposure on April 22. Two mornings earlier John Mirtle captured the comet's softly glowing tail in color (below). Mirtle used a 6-inch f/4.5 reflector, Scotch Chrome 400 film pushed to ISO 1600, and a 1-minute exposure.

To record the nucleus of Comet Austin, Anthony Ducharme used a 3.1-inch f/15 refractor, Fujichrome film, and a 10-minute exposure (bottom). Chris Schur's portrait of Austin on April 20 reveals fine details in the comet's tail (below left). Schur used an 8-inch f/1.5 Schmidt camera, hypersensitized Tech Pan film, and a 3-minute exposure. Ronald Royer employed an 18-inch f/7 reflector, IIIa-F film, and a 7-minute exposure to capture the comet in a close-up portrait on April 19 (left).







COMET MEETS GALAXY in this photo showing Austin and M31 on the morning of April 28. Photo by Jeff Clymmer.

THOUGH DIMMER THAN ANTICIPATED, COMET AUSTIN DELIGHTS OBSERVERS

Long-awaited Comet Austin made its appearance in the early morning sky in April, providing observers and astrophotographers with the chance to enjoy a bright, active comet. Although Austin failed to live up to early brightness predictions, April witnessed the comet shining at magnitude 4.5 and sporting a tail nearly 10° long as it moved through Aries, Pisces, and Andromeda.

Thomas Randall, an observer from Poughkeepsie, New York, wrote in his report, "This morning (April 23) I had my first look at Comet Austin, from the same spot where I observed Halley's Comet in 1986. I arrived at 3:45 a.m. and began scanning the horizon. At first I did not see Austin but did spot M31, which I knew marked the area of the comet. With 8x40 binoculars I could see M31 and several stars in the field. On closer inspection, one of the stars was actually the comet, showing a small, faint tail. The comet's magnitude

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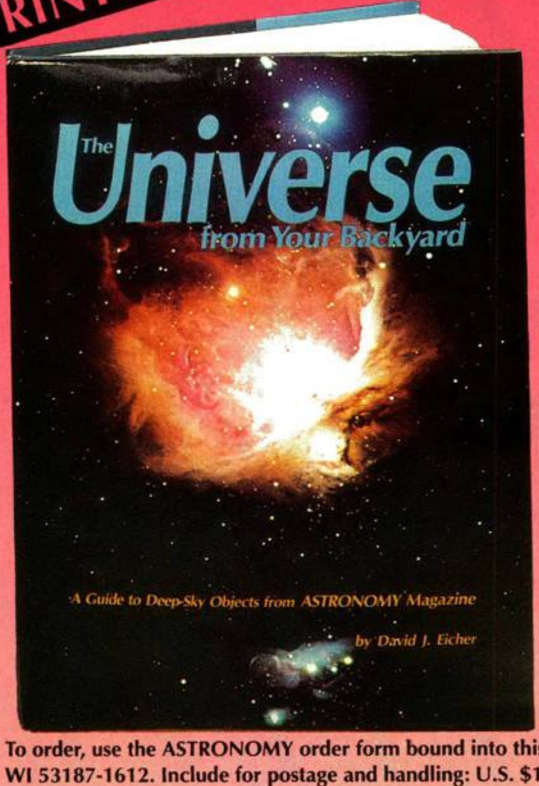

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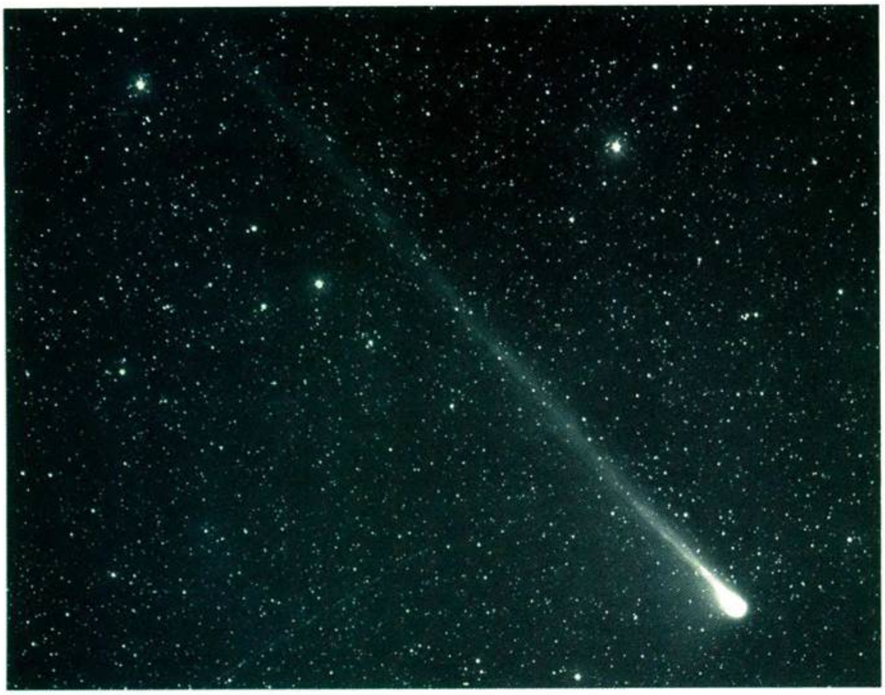

A TAIL SPANNING 8° characterized Comet Austin on April 27. Photo by Chris Schur.

was approximately 4.5. I could not see the comet with the naked eye. At about 4:45 a.m. I lost the comet in the increasing glare of twilight."

Dennis Sørensen of Horsens, Denmark, wrote, "It was very disappointing to observe the comet in the evening hours in early April. The usual haze along the horizon made it nearly impossible to glimpse the comet, even with binoculars. But as it rose into the morning sky, it became a very easy object in my 10x50s. I could follow the tail out to a length of about 4°."

Bob Yen, an astrophotographer from Pasadena, California, said, "I was intending to go to Baja for the San Felipe 250 off-road race, but mechanical failure stopped me near Coachella, California. I got a couple of good photos very late in morning twilight on April 23 and 24. A wild dog was harassing me. It would bark, then I'd hear nothing, and then, closer and louder, barking again. During the day, I was eaten alive by psycho flies. For the comet's sake, I wish I'd made it to Baja! Skies there are really dark." — *David J. Eicher*

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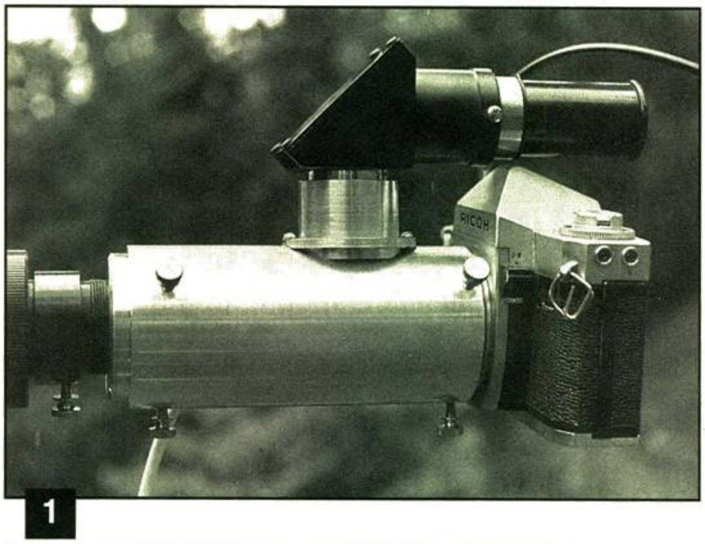

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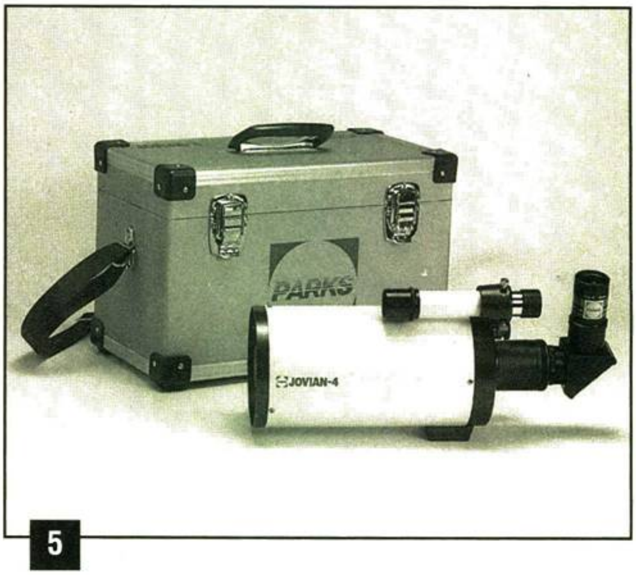
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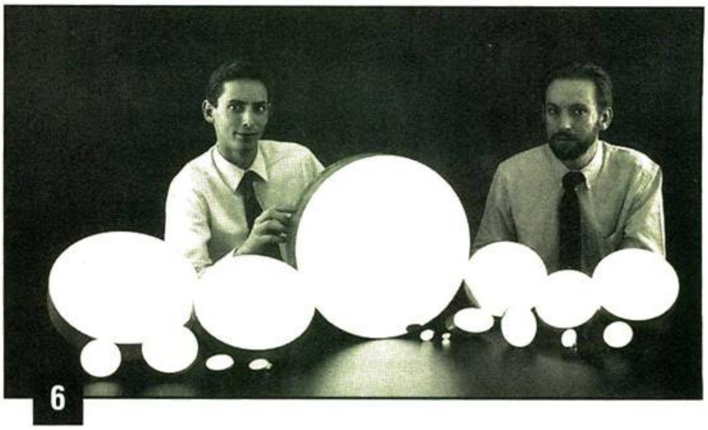

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1 Don Parker Planetary Monitor

This eyepiece projection adapter has a mirror that allows you to monitor the planets or Moon for the moments of best seeing. The shutter on your camera body is left open and the exposure is made with the Monitor's own vibrationless air-controlled shutter. Includes an eyepiece extension tube and a male T-adapter to fit 35mm cameras. The Monitor can be used with a star diagonal; specify 1-1/4 or 2-inch when ordering. The Monitor does not include eyepieces, star diagonal, or 35mm camera body. The projection eyepiece must have a 1-1/4-inch barrel and the monitoring eyepiece a focal length between 40mm and 80mm.

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2 Jack Newton Cold Camera for Telephoto Lenses

The Newton Cold Camera, previously usable only for prime focus photography through a telescope, is now adaptable for use with telephoto lenses. Owners of previous models can retrofit their units (they need to send an extension ring that matches their camera lens mount); purchasers of new units can purchase the telephoto adapter option.

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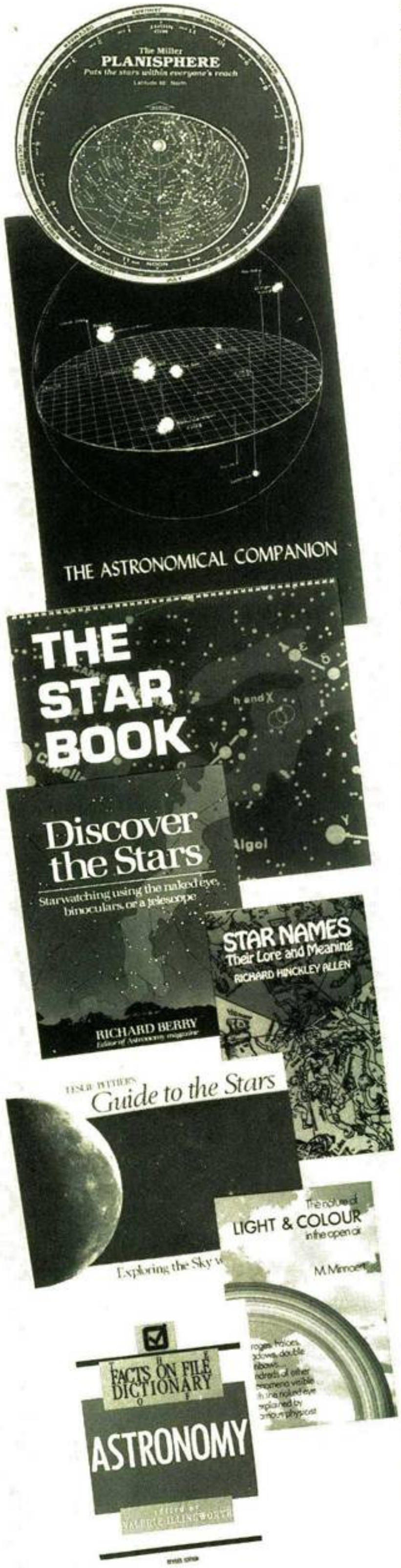

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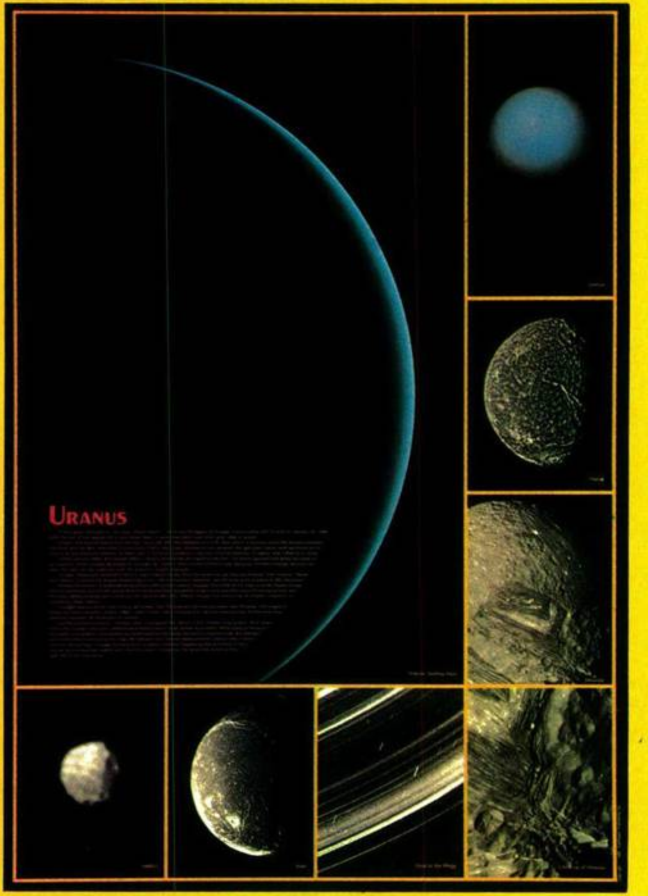

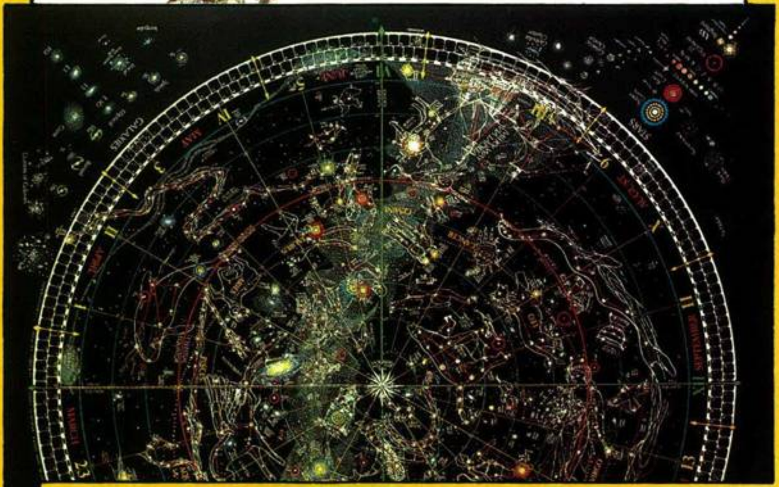

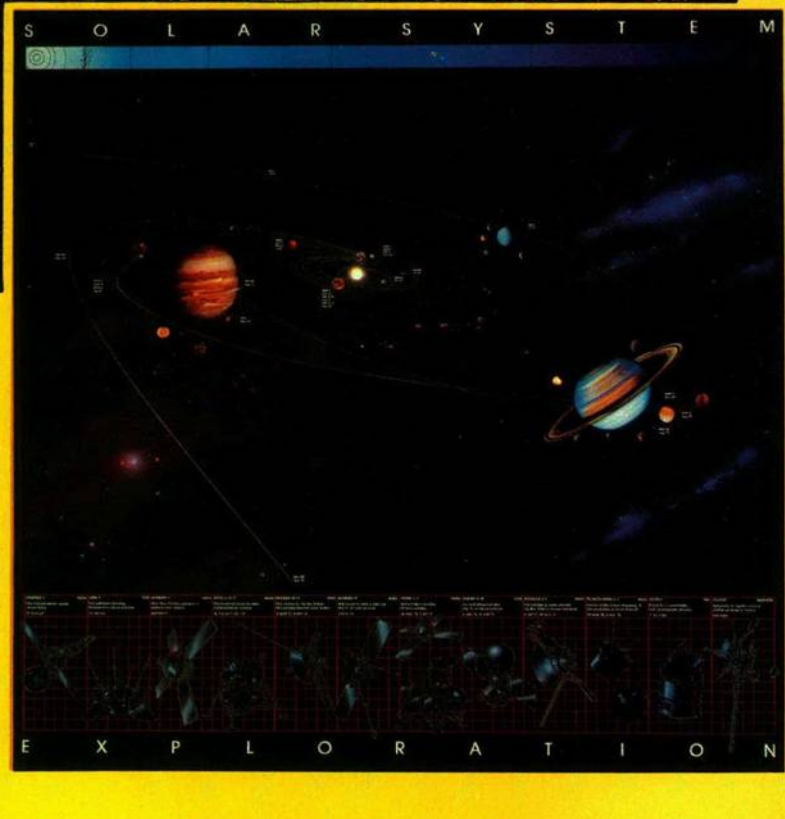

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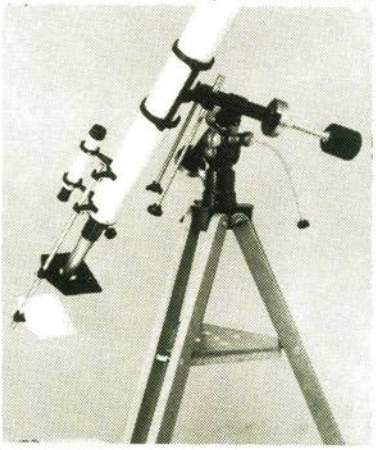

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40mm Wide Field Eyepiece, (TeleVue, 20 Dexter Plaza, Pearl River, NY 10965; (914) 735-4044), list price $360.00.

A decade ago $1,000 would have bought you a couple of dozen eyepieces, more than you could ever use. Now you can spend that amount on just a handful of eyepieces, like the five top-of-the-line models we looked at for this review. This month we'll compare the giant 40mm wide-angle eyepieces from Meade and TeleVue. Next month it's the 13mm and 12mm TeleVue Naglers versus the 14mm Meade Ultra-Wide.

First, the 40mm eyepieces. Meade calls theirs a "Super Wide" while TeleVue calls theirs a "Wide Field." Both have the same apparent field of view, 65°. This wide apparent field combined with the low power of a 40mm eyepiece results in as wide an *actual* field of view as you can get with commonly available eyepieces. This 65° field is in the same league as conventional Erfle and König eyepieces, though both Meade and TeleVue claim their designs improve upon these older wide-angle models. In some respects, such as fewer ghost reflections, they do. However, the Super Wides and Wide Fields still have some off-axis aberrations, primarily astigmatism, that turn stars into flying seagulls at the edge of the field. We wanted to compare the two brands to see if one was any better than the other for off-axis star images.

I tested both eyepieces on a 4-inch Astrophysics Starfire refractor, a telescope with a wide, aberration-free field. I also checked them on a Celestron Ultima 8. In both cases, the TeleVue had the slight advantage. With the TeleVue 40mm, off-axis aberrations started to distort stars about halfway from the center to the edge of the field. With the Meade 40mm, aberration effects could be noticed starting at about 35 percent of the way from the center to the edge, making the Meade's central aberration-free zone slightly smaller than the TeleVue's. The Meade also had slightly greater aberration at the very edge. For example, when I looked at a faint star grouping near the edge of the field, stars looked tighter and more star-like in the TeleVue, though the degree of aberration in both eyepieces was as low or lower than in other wide-angle eyepieces (with the exception of Naglers and Ultra-Wides), even surpassing many high-end Plössls.

Both had excellent eye relief; it was possible to see the entire field even with eyeglasses on. The Meade and TeleVue were equally crisp and sharp at the center of the field. When I looked at bright stars and planets, both were free of color, ghost images, and lens flares, remarkable for multi-element wide-angle eyepieces and a definite improvement over conventional Erfle designs.

Both eyepieces fit only 2-inch focusers. The Meade 40mm is slightly smaller than the TeleVue and weighs 1 pound 8 ounces, versus the TeleVue's hefty 1 pound 15 ounces. In fact the 40mm TeleVue is one of the heaviest eyepieces on the market and can pose a problem on many telescopes, perhaps requiring you to install a counterweight to re-balance your scope.

SUPER WIDE ANGLE 40mm MULTI-COATED
TELE VUE 40mm

THE 40MM WIDE-ANGLE EYEPIECES from Meade and TeleVue are two hefty but excellent units.

Each sell for a street price of about $250 to $300, considerably lower than the manufacturers' suggested list prices. The TeleVue is usually $20 to $40 higher at most outlets, despite the Meade's higher list price. Which is better? I'd pick the TeleVue. But considering that the difference in performance was not major and that the Meade is lighter and less expensive, the Meade 40mm is certainly worth recommending. Keep in mind that the performance of these two models can't be taken as indicative of the entire product line.

Next month we'll compare three other premium eyepieces, the Nagler 12mm and 13mm and the Meade UWA 14mm. — *Alan Dyer* ☐

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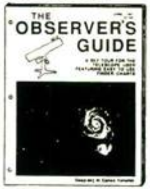

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WHERE DO CRATERS COME FROM?

Impact Cratering by H. J. Melosh, (Oxford University Press, 1988), ISBN 0-19-504284-0, hardcover, 245 pages, $65.

Fifty years ago, few scientists doubted that lunar craters were the products of volcanos; today few of them would question that impact cratering is one of the most fundamental solar system processes, both on the Moon and many other objects.

Jay Melosh's monograph, subtitled "a geologic process," is a technical survey of a relatively new, but mature, field that encompasses craters ranging in size from the microscopic to large regions on planets. Melosh, who is at the University of Arizona's Lunar and Planetary Laboratory, is best known for his computer models of the Earth/planetoid collision that likely formed the Moon.

While most ASTRONOMY readers would probably not find buying this book worth the money, you could easily spend a very enjoyable hour or two with it in a library. The first two chapters (a history of impact-as-an-idea and illustrated description of crater types) are completely open to lay readers. The remaining ten chapters are also largely accessible (just skip the equations), and all the illustrations and figures have clear and informative captions. Each chapter closes with an annotated bibliography.

This is one of those rare technical works that many interested planetary science buffs will get something from.
— *Robert Burnham*

COMET BOOK LACKS SUBSTANCE

Searching for Comets: Deciphering the Secrets of Our Cosmic Past by Louis Brewer Hall, (McGraw-Hill, 1990), ISBN 0-07-025633-0, hardcover, 214 pages, $17.95.

It has been four years since Comet Halley swept through our solar neighborhood. Six separate spacecraft observed the comet up close while thousands of amateur and professional astronomers observed it with Earth-based and Earth-orbiting instruments. As a result of the largest coordinated observing program in the history of science, impressive advances in understanding cometary phenomena were made. By now we should expect an up-to-date book outlining these results for the layperson. Unfortunately, *Searching for Comets* is not that book.

Beginning with a discussion of the 1973-74 *Skylab* flight and the astronauts' observations of Comet Kohoutek, the author sketches the unsuccessful attempts to get NASA to launch spacecraft to Comet Halley. Some details are then presented on how NASA diverted an existing spacecraft in solar orbit to fly through the tail of Comet Giacobini-Zinner in September 1985. The section on the preparations and results of the Soviet, Japanese, and European missions to Comet Halley is far too cursory. The last half of the book focuses on the *Spartan* spacecraft that was designed to image Comet Halley at ultraviolet wavelengths from above Earth's atmosphere. The tragic explosion of the space shuttle *Challenger* in January 1986 ended the *Spartan* program before any observations were made.

Search for Comets is written in an anecdotal style with an emphasis on the personalities of the participating scientists. There are many peripheral but interesting asides. For example, the entrance to the spacecraft clean room at Cape Kennedy is through the men's room, a holdover from when space was solely a man's world. Although such tidbits make for easy reading, there's little information on comets despite the book's title. It is poorly illustrated and riddled with errors. Too often the author didn't let the truthget in the way of a good story— *Donald K. Yeomans, Jet Propulsion Laboratory*

DEEP-SKY OBSERVING WITH BINOCULARS

Deep-Sky Objects for Binoculars by John T. Kozak, (Sky Publishing, 1988), ISBN 0-933346-50-6, softcover, 127 pages, $9.95.

This is an excellent guidebook for observers with dark skies, good-quality binoculars, and some patience. The book is divided into three main chapters. The first discusses the mechanics and optics of binoculars. Chapter two covers observing techniques and tips. Chapter three, roughly half the book, contains brief descriptions of over 130 deep-sky objects for binocular observers in the Northern Hemisphere. Most of these deep-sky objects are well within the range of 7x50 and larger binoculars, though the author is up-front about the fact that some of them may be quite difficult (the California Nebula, for example). Kozak's book is perfect for beginners who have just bought their first binocular and want a list of deep-sky objects to look for. — *Jeff Kanipe*

BRIEF NOTES

Astrophysics

Dynamics of Astrophysical Discs, edited by J. A. Sellwood, (Cambridge University Press, 1990) ISBN 0-521-37485-5, hardcover, 257 pages, $47.50.

Dynamics of Astrophysical Discs is a collection of scientific papers given during a conference held at the University of Manchester, England, in December 1988 on recent developments in both theory and observations of disk systems. The book is intended as a reference work for professional astronomers and postgraduate students.

Papers address the dynamical behavior of disks in a wide variety of objects, such as planetary ring systems, stars, protoplanets, and galaxies. Papers include "Structure of the Uranian Rings," "The β Pictoris Disc: a Planetary Rather Than a Protoplanetary One," "Long-Lived Spiral Waves in N-Body Simulations," and "Tidal Triggering of Active Galaxies by Rich Clusters."

Stellar Structure and Evolution by R. Kippenhahn and A. Weigert, (Springer-Verlag, 1990), ISBN 3-540-50211-4, hardcover, 468 pages, $49.95.

Kippenhahn and Weigert are two German astrophysicists well-known for their pioneering work in stellar modeling. They have written a textbook that gives a complete and comprehensive treatment of the astrophysical processes involved in the interiors of stars. The purpose of their book is to help the student and researcher understand the stellar models that have been developed over the years to explain the stability, dynamics, and evolution of stars. What makes the book especially valuable is that much of the text is based on the authors' own work.

General Astronomy

Merlin's Tour of the Universe by Neil De Grasse Tyson (Columbia University Press, 1989), ISBN 0-231-06924-3, hardcover, 300 pages, $29.95.

A question-and-answer book can be fun if the questions are appealing and the answers are lively. *Merlin's Tour* is just such a book. The questions range from the commonplace ("Exactly what is a black hole?") to the off-the-wall ("If the Earth were to explode tomorrow, what would happen to the orbits of the other planets?"). Tyson's answers are glib and just a little tongue in cheek. Chapters cover the solar system, stars, galaxies, and the universe. A glossary is also provided. ☐

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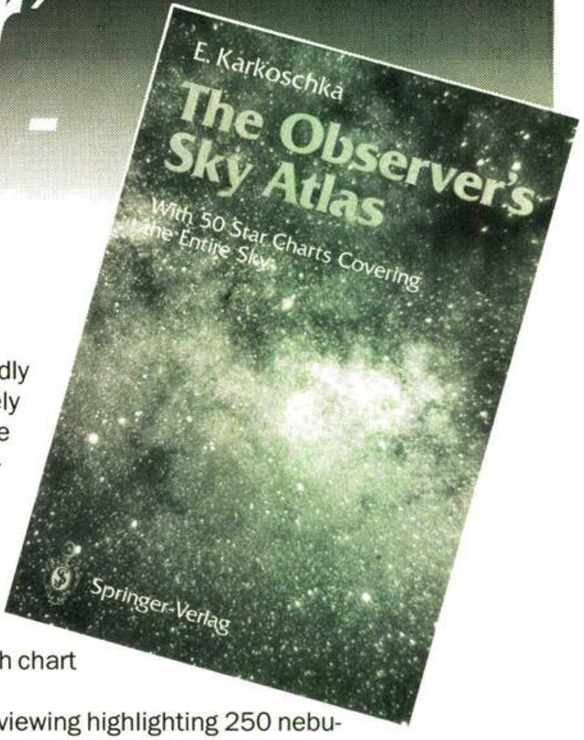

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Meetings & Events

July 31-August 4
Astronomical League National Convention, Washington University, St. Louis, Missouri. Sponsored by the St. Louis Astronomical Society. Contact: Steve Best, 6943 Amherst Avenue, University City, MO 63130.

August 17-18
Starfest '90, Riverplace Campground, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5. Phone: (416) 761-1798.

August 17-19
The Conjunction, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Richard Sanderson, P.O. Box 54, Monson, MA 01057.

August 17-19
Front Range Astronomical SuperCluster Star Party, Fox Park, Wyoming. Sponsored by the Cheyenne and Denver Astronomical Societies. Contact: Robert Stencel, University of Colorado, Campus Box 391, Boulder, CO 80309. Phone: (303) 492-4050.

August 17-19
Northwoods Starfest, Eau Claire Youth Camp, Beaver Creek Reserve, Wisconsin. Sponsored by the Chippewa Falls Astronomical Society. Contact: Kevin Litten, 921 West Willow, Chippewa Falls, WI 54729. Phone: (715) 726-2382.

August 17-19
2nd Annual Southern Minnesota Sky Show, near New Ulm, Minnesota. Sponsored by the Minnesota Valley Amateur Astronomers. Contact: M.V.A.A., Route 4, Box 15A, New Ulm, MN 56073.

August 17-20
Nova East '90 Star Party, Fundy National Park, New Brunswick. Contact: Halifax Centre of the R.A.S.C., 1747 Summer Street, Halifax, Nova Scotia, Canada B3H 3A6.

August 17-24
Meteor '90 Convention, Ráktanya, Hungary. Sponsored by the Hungarian Astronomical Association. Contact: H.A.A., 1253 Budapest, P.O. Box 36, Hungary.

August 18
Prairie Astronomy Club Picnic and Star Party, Hyde Observatory, Holmes Park, Lincoln, Nebraska. Contact: Prairie Astronomy Club, P.O. Box 80553, Lincoln, NE 68501.

August 18-20
3rd Annual Oregon Star Party, Steens Mountain, Frenchglen, Oregon. Sponsored by the Rose City Astronomers of Portland. Contact: Chuck Dethloff, 15111 NW Oakmont Loop, Beaverton, OR 97006. Phone: (503) 629-2145, or Dale Fenske (503) 256-1840.

August 22-26
Mount Kobau Star Party, near Osoyoos, Brit-

ish Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

August 24-26
4th Annual Astronomy Rendezvous and Conference, Normal, Illinois. Sponsored by the Twin City Amateur Astronomers. Contact: Twin City Amateur Astronomers, P.O Box 755, Normal, IL 61761.

September 8
StarConn '90, Wesleyan University, Middletown, Connecticut. Sponsored by the Astronomical Society of Greater Hartford. Contact: Suzanne Marinan, 367 Suger Hill Road, Tolland, CT 06084-2116.

September 14-15
4th Annual Observing Party, Cathedral Gorge State Park, Panaca, Nevada. Sponsored by the Las Vegas Astronomical Society. Contact: Jim Mellor, Great Western Hotels, 401 South Casino Center Boulevard, Las Vegas, NV 89101. Phone: (800) 634-6635.

September 14-16
Astrofest '90, Kankakee River State Park, Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477.

September 14-16
4th Annual Whirlpool Star Party, Birr, County Offaly, Ireland. Sponsored by the Limerick Astronomy Club. Contact: Tony O'Hanlon, 26 Ballycannon Heights, Meelick, County Clare, Republic of Ireland.

September 18-23
Okie-Tex Star Party, Lake Murray State Lodge, near Ardmore, Oklahoma. Sponsored by the Oklahoma City Astronomy Club. Contact: Okie-Tex Star Party, c/o Beryl Cadle, 6616 NW 20th, Bethany, OK 73008.

September 20-21
Iowa Convention of Amateur and Professional Astronomers. Contact: C.L. Allen, c/o Des Moines Astronomical Society, 2307 49th Street, Des Moines, IA 50310-2538.

September 20-22
3rd Annual Ozarks Star Party, near Joplin, Missouri. Contact: Don Walton, 2626 Illinois, Joplin, MO 64804. Phone: (417) 623-3972.

September 22, October 20
6th Annual Blue Ridge Parkway Regional Stargaze, Julian Price Park, near Blowing Rock, North Carolina. Contact: Greg Kirby, 12 East Street, Granite Falls, NC 28630. Phone: (704) 396-7656. □

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information.

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Readings and Resources

Cosmic Jets (page 28)

Exploration of the Universe by George Abell, David Morrison, and Sidney Wolff, (Saunders, 1987). Pages 635 to 640 of this fine textbook provide background information and an overview of radio sources and cosmic jets.

"The Curious Case of Cosmic Jets," by Jeff Kanipe, ASTRONOMY, March 1989. Describes how jets are influenced by the intergalactic environment and the "engines" that power them.

Telescope Tune-Up (page 66)

"Inside the Well-Baffled Newtonian," by Richard Berry, *Deep Sky*, Winter 88/89. A detailed "how-to" article that shows you how to eradicate stray light from your Newtonian reflector.

"The Art of Seeing," by Michael Porcellino, ASTRONOMY, February 1990. Once you've improved your telescope for maximum contrast, you still need to improve your ability to see faint objects. This article tells you how.

Galaxies of Cetus (page 72)

Deep Sky Observing with Small Telescopes by David J. Eicher and the editors of *Deep Sky*, (Enslow Publishers, 1989). An introductory guidebook to observing that features hundreds of objects, including the most attractive and noteworthy sights in Cetus.

CREDITS

Cover: Tony Hallas and Daphne Mount, 14-inch SCT at f/7.5, Fuji Super HG 400 film; page 4: Canada-France-Hawaii Telescope Corporation; page 12: drawing by Greg Kot; page 22: Susan Neff, NASA Goddard Space Flight Center; page 24: photos by William Albrecht, 1-second exposures at f/1.9 on Kodak T-Max at ISO 3200; pages 28-29: painting by Thomas L. Hunt; pages 30-31: courtesy Alan Bridle, David Hough, and Jack Burns; page 32: courtesy Larry Rudnick and Jack Burns; page 33: courtesy Jack Burns; pages 34-35: radio image courtesy David Clark and Jack Burns, photo of NGC 5128 courtesy Anglo-Australian Telescope Board; pages 36-37: schematic courtesy of Jack Burns, photo of 3C 219 courtesy of David Clarke, photo of M87 courtesy of the National Radio Astronomy Observatory/Associated Universities, Inc.; pages 38-39: NASA; pages 40-42: Stephen Cole; page 43: NASA; page 44: painting by William K. Hartmann and Ron Miller; page 52: photo by Mark Payne-Gill, taken at the August 17, 1989, lunar eclipse from Buckinghamshire, England, with a 300mm f/5 lens and a 5-second exposure on Fuji 100D film; page 54: photo by Dan and Nancy Ostergaard taken August 12, 1981, with an 80mm f/2.8 lens and a 13-minute exposure; pages 60-61: videography by David Brewer, photographed by M. Barlow Pepin; page 62: Michael Chibnik; pages 63-65: videography by David Brewer, photographed by M. Barlow Pepin; pages 66-70: drawings by Greg Kot; page 72: Kim Zussman, modified 11-inch f/10 SCT, hypersensitized Tech Pan film, 105-minute exposure; page 73: Jack Newton, 16-inch f/5 reflector, 15-minute exposure; page 74: Kim Zussman, modified 11-inch f/10 SCT, hypersensitized Tech Pan film, 150-minute exposure; page 75, top: Mace Hooley, 17.5-inch f/4.5 reflector, SR 1600 film, UV filter, 10-minute exposure; page 75, bottom: Jeffrey L. Jones, 8-inch f/10 SCT, hypersensitized Tech Pan film, 120-minute exposure; page 77: Martin C. Germano, 8-inch f/5 reflector, hypersensitized Tech Pan film, 45-minute exposure; page 81: Merry Edenton-Wooten, photos taken on April 29, 1990, using a 28mm f/2.8 lens, Ektachrome 400 film, and 30-second exposures; page 82, top left: Ronald Royer, 18-inch f/7 reflector, IIIa-F film, 7-minute exposure on April 19, 1990; page 82, bottom left: Chris Schur, 8-inch f/1.5 Schmidt camera, hypersensitized Tech Pan film, 3-minute exposure on April 20, 1990; page 82, center: John Mirtle, 6-inch f/4.5 reflector, Scotch Chrome 400 film pushed to ISO 1600, 1-minute exposure on April 20, 1990; page 82, bottom center: Anthony Ducharme, 3.1-inch f/15 refractor, Fujichrome film, 10-minute exposure on April 22, 1990; page 83: Andreas Gada, 75mm f/4.5 lens, T-Max P3200 film pushed to ISO 25,000, 5-minute exposure on April 22, 1990; page 84: Jeff Clymmer, 135mm f/4 lens, hypersensitized Tech Pan film, 10-minute exposure on April 28, 1990; page 85: Chris Schur, 8-inch f/1.5 Schmidt camera, hypersensitized Tech Pan film, 5-minute exposure on April 27, 1990.

READER EXCHANGE

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WANTED — Persons interested in astronomy and who live in Northwestern Ontario to join the R.A.S.C.-Thunder Bay Centre. Contact R.A.S.C., Thunder Bay Centre, 135 Hogarth Street, Thunder Bay, Ontario, P74 7H1.

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ANNOUNCEMENT — The Bucks-Mont Astronomical Association meets at 8 PM on the first Wednesday of each month in the farmhouse at Tamenend Park, Second Street Pike, Southampton, PA. Contact Bob Post. Phone (215) 322-8284.

ANNOUNCEMENT — Join a new group in the Las Cruces area — the Third Quarter Association. With scheduled monthly observing sessions; plus receive a subscription to *Deep Sky* magazine. Help preserve dark skies with your dues of $15 yearly. Contact the Third Quarter Association, P.O. Box 56, Radium Springs, NM 88054.

ANNOUNCEMENT — We are a newly formed club in eastern North Carolina and welcome new members. We meet on the 1st Monday of each month on the new campus of Wayne Community College in room LC217 at 7:30 PM. Contact Robert Krieger, 1607 Munroe Lane, Goldsboro, NC 27534.

ANNOUNCEMENT — The Santa Barbara Astronomy Club meets on the first Thursday of each month at 7:30 p.m. at the Carroll Observatory, on the campus of Westmount College, Santa Barbara, California. Contact Clyde Kirkpatrick, SBAC, P.O. Box 3702, Santa Barbara, CA 93130. Phone (805) 685-2705.

ANNOUNCEMENT — The 8th Annual Northern Virginia Telescope Meet is October 19-20 at C. M. Crockett Park, Calverton, VA. Contact Al Schumann, 6121 Rivanna Drive, Springfield, VA 22150. Phone (703) 256-4777 or leave message on (703) 256-8359.

ANNOUNCEMENT — Twin Lakes star party. October 19-20. Sponsored by West Kentucky Amateur Astronomers. Contact Jim Boren, Land Between The Lakes, Golden Pond, KY 42211-9001. Phone (615) 232-7405 days or (615) 232-6820 evenings.

ANNOUNCEMENT — May 5, 1990 is Astronomy Day at the Museum of Arts and Sciences, Macon, Georgia. Sponsored by the Museum of Arts and Sciences with the Middle Georgia Astronomical Society. Contact Astronomy Day, Museum of Arts and Sciences, 4182 Forsyth Road, Macon, GA 31210.

ANNOUNCEMENT — Astronomy Day 1990. May 15, 1990, Mattatuck Community College, Waterbury, CT. Sponsored by the Mattatuck Astronomical Society. Contact M.A.S., Math Science Division, Mattatuck Community College, Waterbury, CT 06708.

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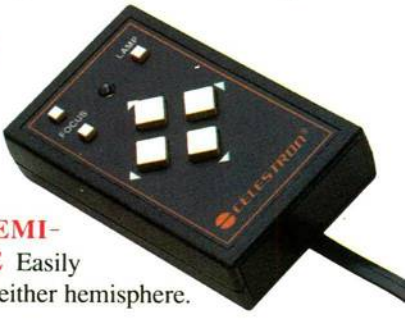

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